ARS Workshop on Improving the Photosynthetic Capability and Biological Conversion of Solar Energy by Crops

January 21-23, 1975

Urbana, Illinois

March 1975

INDV

ARS Workshop Agenda on Improving the Photosynthetic Capability and Biological Conversion of Solar Energy by Crops*

Urbana, Illinois

January 21-23, 1975

January 21, 1975

Tuesday Morning

8:00-8:15	Welcome--R. W. Howell, University of Illinois Welcome--R. W. Rinne, North Central Region, ARS
8:15-8:30	Workshop Objectives -- W. C. Shaw
8:30-8:40	Workshop Format -- N. J. Chatterton
8:40-12:30	Introduction of participants. Presentations by each ARS participant (10 minutes or less). Presentation of concepts and current program--not a detailed report of results.
12:30-2:00	Lunch and informal discussions

Tuesday Afternoon - Directed Discussions -- Emphasis on:

(a) where are we?, (b) what is missing?, and (c) what needs to be done?

2:00-3:30	"Physiological and Biochemical Mechanisms of Photosynthesis" - W. L. Ogren - Discussion Leader
3:30-5:00	"Leaf and Whole Plant Aspects of Photosynthesis Including Metabolism and Translocation" - J. R. Mauney - Discussion Leader

Tuesday Evening

6:30-7:30	Social Hour - University of Illinois Faculty Club
7:30-10:00	Dinner and Informal Discussions - University of Illinois Faculty Club

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a. Organizing Committee -- N. J. Chatterton, Chairman; D. N. Baker, G. E. Carlson, E. R. Lemon, J. R. Mauney, and W. L. Ogren

b. General Workshop Chairman -- W. C. Shaw, National Program Staff

January 22, 1975

Wednesday Morning - Directed Discussions Continued.

9:00 - 10:30	"Canopy Geometry, Crop Growth, Microclimate, and Environment as Related to Photosynthesis" -- E. R. Lemon -- Discussion Leader
10:30-12:00	"Dynamics of Photosynthetic Production--Systems Analysis" -- D. N. Baker -- Discussion Leader
12:00-1:00	Lunch

Wednesday Afternoon

1:00-3:00	Summary of "Needs, Priorities, and Recommendations" - C. J. Arntzen, G. E. Carlson, O. Bjorkman, W. G. Duncan, R. S. Loomis, D. N. Moss, and R. B. Musgrave
3:00-5:00	ARS Discussion Leaders meeting with participants in four separate groups for drafting of preliminary report.
5:00	Summary by W. C. Shaw, W. A. Raney, R. E. Coleman, and R. W. Howell
5:30	Workshop Adjourns

January 23, 1975

Thursday Morning

9:00-12:00	Meeting of Organizing Committee and NPS-PACS to draft report of Workshop.

ARS Workshop on Improving the Photosynthetic Capability and Biological Conversion of Solar Energy by Crops

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Part I Review of Current Concepts and Programs by ARS Participants

A Statement of Research Requirements in Photosynthesis

Donald N. Baker

Every dedicated scientist, that I know of, is interested in seeing his research applied for the betterment of man's existance on earth. And photosynthesis is the energy source for all life on earth. I began my studies of light interception and photosynthesis in crop canopies during a period of declining research budgets. I could appreciate that some areas of agricultural research could be cut - but surely not mine - after all I was dealing with the ultimate limit to crop yield. But we too were being cut and eventually I decided that in order to prevent this it would be helpful to demonstrate the relation between photosynthesis and yield in cotton. And that in itself has turned out to be an interesting scientific exercise. This began simply with the calculation of hourly increments of net photosynthate production from flowering to harvest. Hesketh joined us in 1968 and we arrived at the conclusion that a typical cotton crop should be able to produce 5.7 bales per acre if all photosynthate were directed into boll growth. This is about 3 times what is typically made in our climate and I was told later by executives of Cotton Incorporated - a large grower coop which grants large amounts of research money each year - that our findings were the basis of their decision not to fund photosynthesis research but to fund research in the fruiting physiology of cotton. Now this was pretty bewildering - we were accelerating the erosion of support for photosynthesis research.

Working with Bill Duncan, we extended these calculations into the dynamic simulation of plant growth. This model eventually took the form shown in Figure 1. In this model certain manipulations of each day's climate data were made, certain soil processes including the uptake of water and nitrogen were simulated, light interception and canopy photosynthesis and respiration were calculated. And, I would like to note here that in a crop where the ratio of photosynthesizing tissue to total biomass is changing during the course of the calculation, these processes must be handled separately. Your old net CO_2 uptake data won't suffice. You must have gross photosynthesis. Nitrogen and carbohydrate were distributed among the various growing points. Decisions were made about where to begin or terminate the growth of the various tissues in the plant, and at the end of the season diagrams of the plant as it appeared each day were drawn.

One of the first things we wanted to do with this thing after we got it running and checked out was to see what would happen when we multiplied each day's photosynthate production by a factor. Now, it turns out that cotton, soybeans, tomatoes and I believe corn, have the capability of starting more fruit than the plant can nourish. Then, physiological stresses develop and fruit are aborted. In Table 1 these stresses in SIMCOT II are represented by the "BOLINC" term. You can see the effect of relative photosynthetic efficiency on plant weight and yield.

The yield response is shown a little better in Figure 2. Now this is very nice. It shows the yield increases we can expect through increased photosynthate production. This is what we would expect, and it may, in fact, represent what would happen in forage crops, sugar

beets. etc. But life is not nearly this simple in cotton , soybeans, tomatoes etc. In cotton, for example, there are nitrogen stresses as well as carbohydrate stresses. Cotton is an indeterminate fruiting perennial and it is absolutely essential that cultural measures be taken to terminate its growth in the fall to facilitate insect control and harvest. In the irrigated West this is done by cutting off the water. In the Mid-south and Southeast it is done by limiting the nitrogen supply. This generally means a yield sacrifice. This is shown in Figure 3. The solid lines represent simulated fruiting in typical commercial crop. The figures represent fruiting in the same crop - but with a 50 percent increase in photosynthetic efficiency. Observe that the normal crop initiated 15 bolls and matured seven. It weighed 43 grams at first bloom on day 73. The crop with a 50 percent increase in photosynthetic efficiency weighed 58 grams at first bloom. Much of the nitrogen was permanently tied up in this plant and not available to the fruit. So, this crop abscised all but one of these bolls. It did, however, produce a much larger vegetative structure, as indicated by the late season squaring and the plant weight.

The opposite of these effects are shown in Figure 4, where photosynthesis is reduced 50-percent. The plant weighed less at fairst bloom, more of the nitrogen was available for boll growth and a higher yeild was obtained.

Now, this model is not perfect and I don't have complete confidence in these yield figures, but the trends seem reasonable, and, we have a suggestion that enhanced photosynthesis will not necessarily result in increased yields in these more complex crops.

A number of prominent photosynthesis researchers (Duncan, Loomsis, Hesketh and Bula are here, De Wit) have taken up the challenge to relate their chosen research topic to crop yield in this way and I think each would admit that it has been a humbling experience.

In Summary:

i. The relation between yield and photosynthetic efficiency is not as simple as one might expect in many crops.

2. The relative value of efforts to make genetic or cultural changes in canopy photosynthesis as compared with efforts to change other processes can be determined through a team effort and systems analysis.

3. Before this can be done - certain types of photosynthesis and respiration experiments must be done. Gross photosynthesis responses to light, and CO_2 as well as to the moisture and nutritional status of the crop must be obtained.

I plead with this group that attention be given to those experiments. There will be an immediate application of the results.

TABLE 1. SIMCOT II. BOLL INCREMENTS AND RESULTING SQUARE ABSCISSION WITH VARIOUS RELATIVE PHOTOSYNTHETIC EFFICIENCIES, AT 20,498 PLANTS PER ACRE.

	REL. P. EFF.=1		REL. P. EFF.=.5		REL. P. EFF.=1.5	
DAY	BOLINC	ABSCISSION	BOLINC	ABSCISSION	BOLINC	ABSCISSION
75-79	.93	1	.60	8	1.0	0
80-89	.82	9	.49	18	.95	1
90-99	.58	26	.33	14	.67	25
100-109	.47	19	.32	3	.51	21
110-119	.40	13	.32	0	.42	16
120-129	.48	11	.47	0	.50	7
130-139	.73	6	.75	0	.76	7
OPEN BOLLS/PLANT	29		15		38	
PLANTS WGT.	185G		97G		252G	
BALES/A	3.0		1.16		4.22	

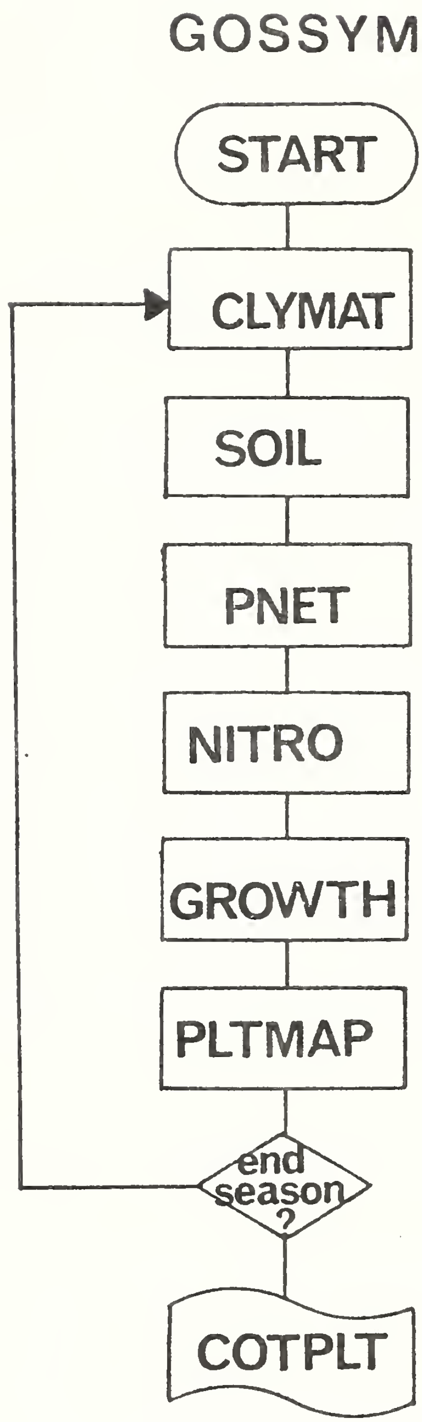

FIGURE 1. Plant simulation model flow chart.

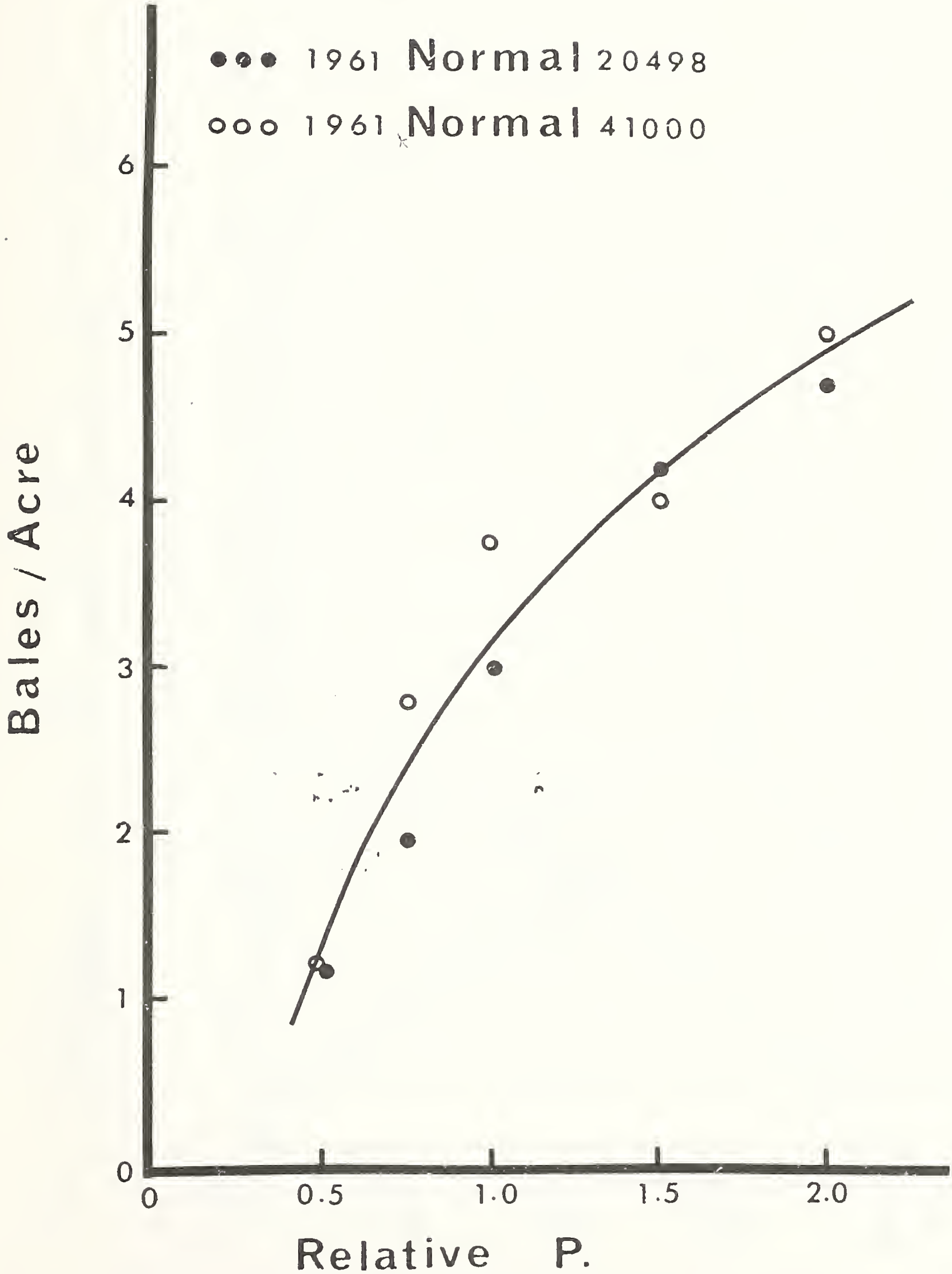

FIGURE 2. Simulated yield vs. relative photosynthetic efficiency in cotton.

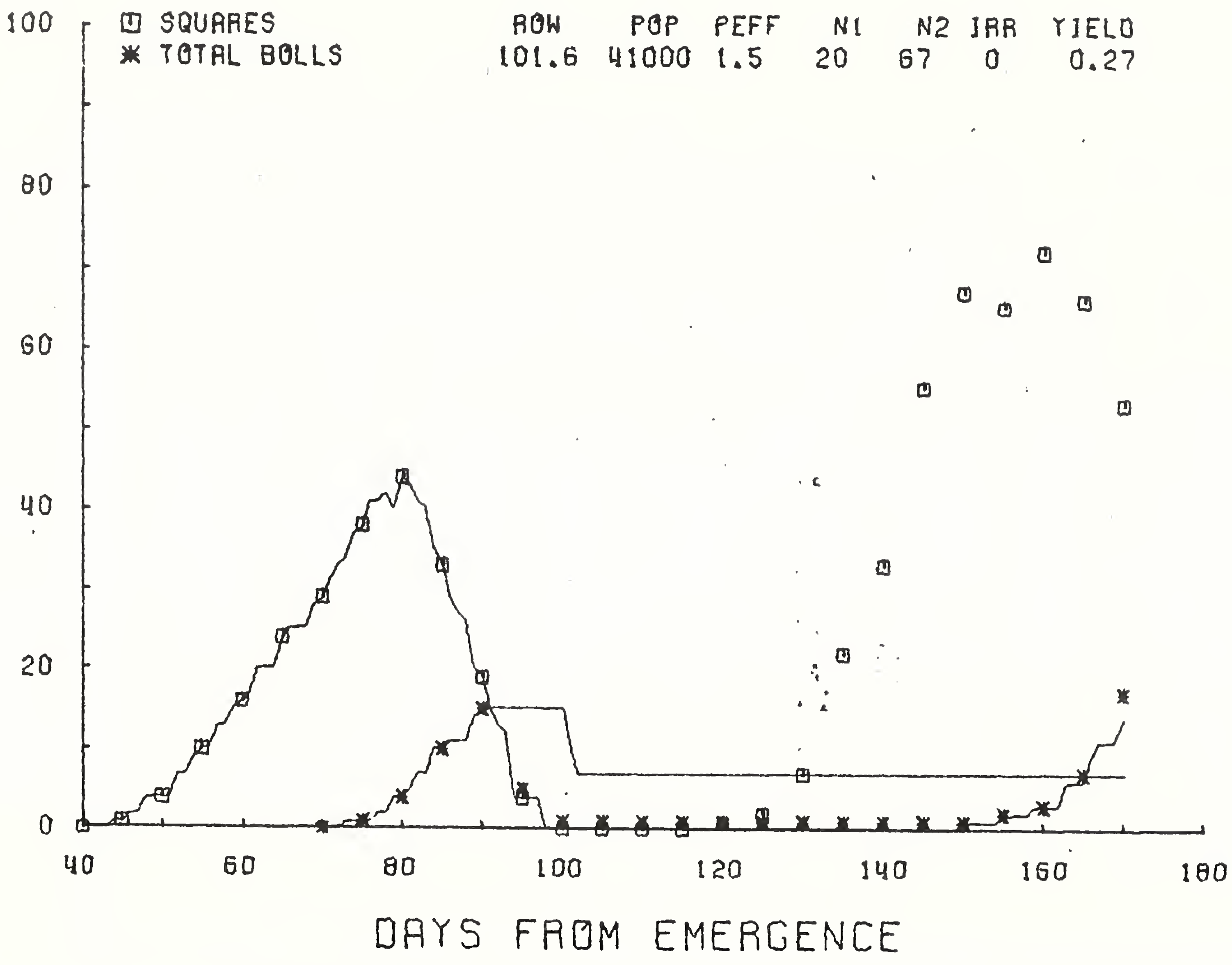

FIGURE 3. Simulated time courses of fruiting in cotton.

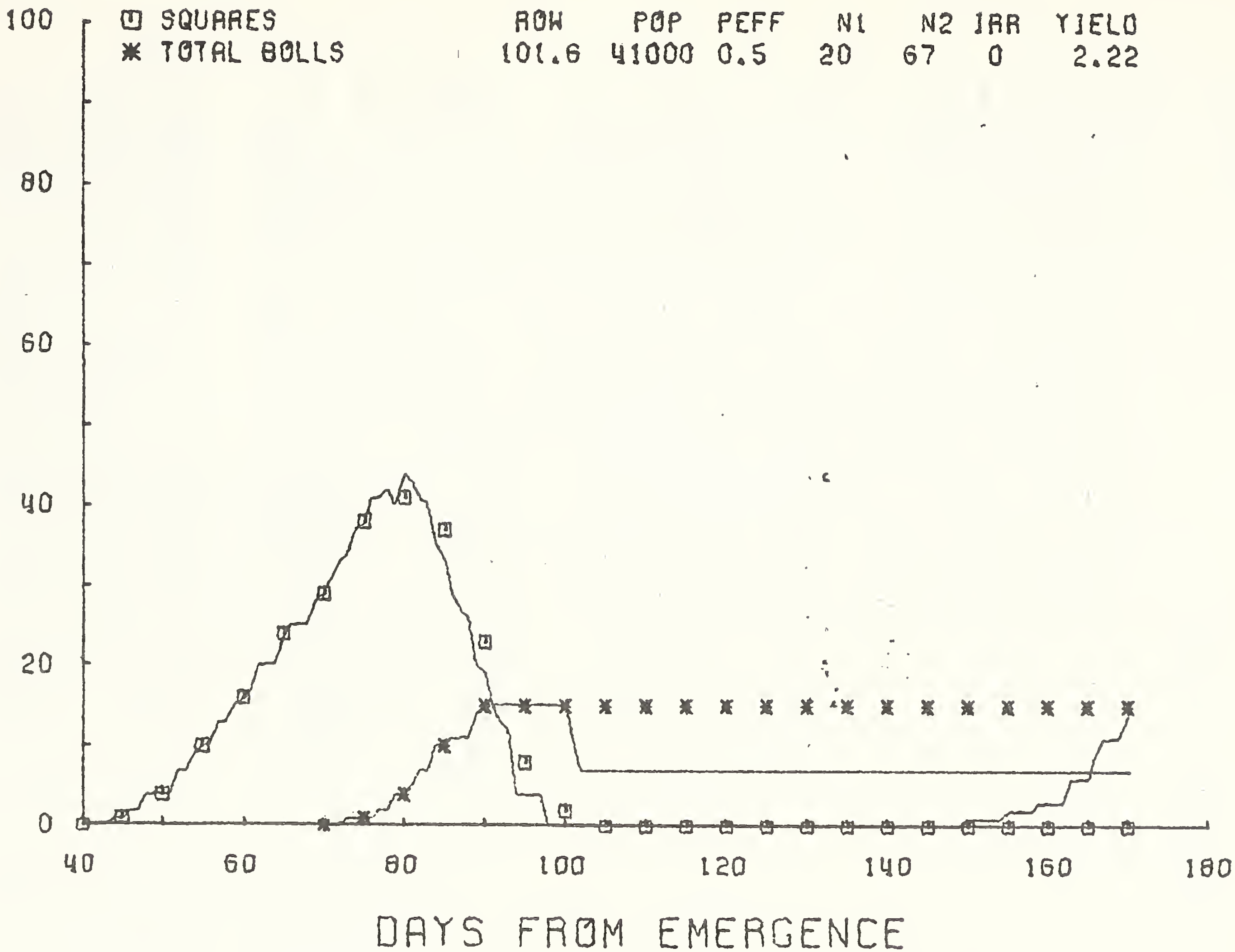

FIGURE 4. Simulated time courses of fruiting in cotton.

Inhibition of Apparent Photosynthesis by
Phytotoxic Air Pollutants
By Jesse H. Bennett
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Sublethal plant exposures to a number of air pollutants can cause the reversible suppression of photosynthesis rates. Agriculturalists are concerned about the possibility that plant growth may be suppressed by atmospheric pollution. Carbon dioxide exchange measurements have been utilized as a screening technique to determine which important air pollutants can depress photosynthetic rates in plants exposed to low pollutant concentrations and dosages. It is possible that several of these phytotoxicants, especially the sulfur and nitrogen oxides, may be of applied value as convenient inhibitors of photosynthetic processes when used for general investigative purposes.

At least six major phytotoxic air pollutants have been shown to reversibly inhibit apparent photosynthesis rates. Studies indicate that these phytotoxicants rank in the following order according to the relative amount of inhibition induced after several hours of exposure to equal pollutant concentrations: $HF > Cl_2 \simeq O_3 > SO_2 > NO_2 > NO$. A summary of experimental results which compare measured depressions in CO_2 uptake rates of barley, oat and alfalfa canopies after 1-hr and 2-hr pollutant exposures to the individual pollutants or to dual pollutant mixtures is given in Figure 1 and Table 1. Typical inhibition and recovery rate curves for treatments that reduced CO_2 absorption rates 20 percent by the end of two hours of exposure are also shown. In contrast to this, equivalent experiments on a plant species (Muhlenbergia asperifolia) that is very resistant to SO_2 showed this grass to require about five times greater SO_2 dosages to effect comparable rate reductions. Responses of many plants subjected to similar environmental treatment conditions would probably fall between this 1:5 sensitivity range. Plants grown and exposed under adverse (i.e. xeric, etc.) cultural circumstance, however, tend to respond less markedly to given pollutant dosages than plants subjected to environments which foster rapid growth. Such plants may appear to be highly tolerant to pollution. Plant age and stage of development also greatly influence plant sensitivity to pollutants.

Although information concerning the inhibition of photosynthesis by air pollution is limited, we may gain a perspective into the potential problem through appraising available data on the extent that CO_2 uptake by plant canopies investigated can be suppressed. Of the pollutants and mixtures tested, O_3, or combinations of SO_2+NO_2, are most likely to occur in ambient atmospheres in sufficiently high concentrations to acutely depress apparent photosynthesis rates. Ambient HF concentrations of the magnitude which inhibited CO_2 uptake in an acute, reversible manner would be rare. Studies into longer-term exposures

to HF concentrations in the low ppb range have suggested that reduced photosynthesis under these conditions correlated with the amount of necrosis that developed.

In concentrations approximating present air quality standards, O_3 or SO_2 in combination with NO_2 could measurably depress CO_2 uptake rates of sensitive plants if exposed under favorable growing conditions. One-hour exposures to 10 pphm O_3 (which is slightly above the primary and secondary standards--i.e., 8 pphm for 1 hr), for example, depressed alfalfa CO_2 absorption rates approximately four percent. Exposures to 15 pphm·hr SO_2 in combination with an equal amount of NO_2 reduced uptake rates by 7%. Alfalfa, barley and oats canopies exposed to these pollutants singly required higher concentrations (i.e., two-hour treatments with more than 20 pphm SO_2 or 40 pphm NO_2) to measurably reduce canopy uptake rates.

Plants live in a world comprised of numerous limiting and potentially destructive forces. These vary with time. A developing biosystem is subjected to the integrated influence of all positive and negative forces that interact simultaneously upon the system. In the complex natural environment, a practical evaluation of the impact of any one factor should not be made without due respect given to the relative influences of all major controlling factors which vary plant responses and perturb the system. It is in this context that the role played by air pollution in affecting our plant resources should be assessed before consequent regulatory actions or management policies and practices are developed.

Summary of U. S. National Ambient Air Quality Standards

Pollutant	Ambient Air Standards	Primary (pphm)	Secondary (pphm)
Sulfur oxides (SO_x)	Yearly mean	3	3
	Max. 24-hr average	14	14
	Max. 3-hr average	--	50
Oxidants (O_x)	Max. 1-hr average	8	8
Nitrogen oxides (NO_x)	Yearly mean	5	5

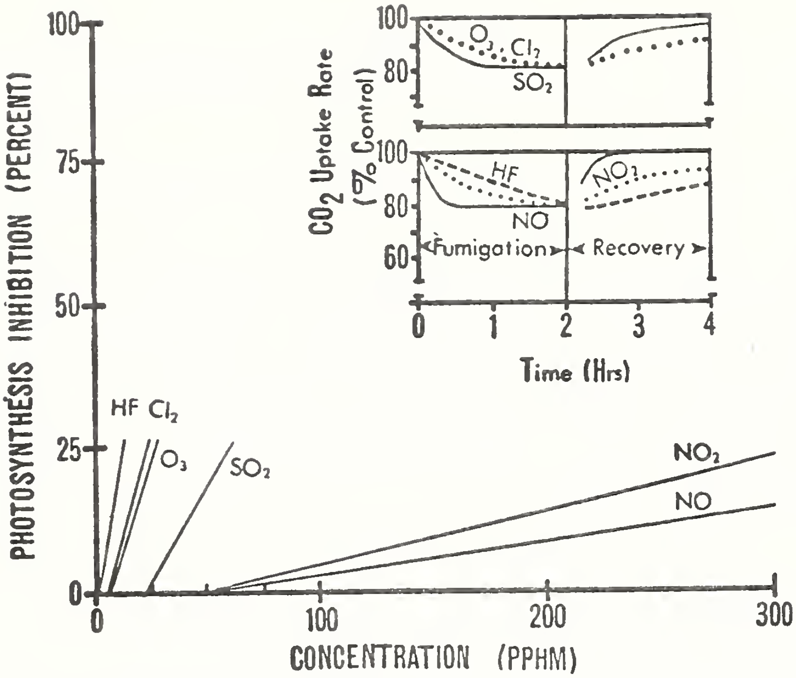

Figure 1. Mean depressions in apparent photosynthetic rates of barley, oat andalfalfa canopies induced by the end of 2-hr air pollutant fumigations. Insert: Typical inhibition and recovery rate curves.

Table 1. Inhibition of apparent photosynthetic rates of alfalfa by 1-hr treatments with single and dual combinations of pollutants.

Pollutant(s)	Conc. (pphm)	n	$\overline{\Delta P}$(% Control)[1]	$\overline{\Sigma\Delta P}$(% Control)
SO_2+NO_2	(15 + 15)	5	7 ± 2**	0
	(25 + 25)	13	9 ± 2**	2 ± 1
	(50 + 40)	7	20 ± 4	23 ± 3
SO_2+O_3	(30 + 10)	5	11 ± 3	10 ± 4
	(30 + 20)	5	19 ± 4	16 ± 5
SO_2+HF	(25 + 3)	5	9 ± 3*	5 ± 2
NO_2+HF	(50 + 3)	5	7 ± 3	6 ± 4
NO_2+O_3	(50 + 10)	3	9 ± 4	7 ± 4

[1] ** and * denote significant means at the P.01 and P.05 levels, respectively.

CONCEPTS OF CURRENT PROGRAM
Presentation for Photosynthesis Workshop
Urbana, Illinois Jan. 21-23, 1975

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The yield of a plant is an expression of its genetic potential to convert solar energy in a given environment. Of fundamental importance are photosynthesis, translocation, synthesis, and respiration. The nice thing about oversimplification is that it is neat and tidy. Over the past several years we have sought to identify genetic variation for photosynthesis (NCE) within a species, namely alfalfa and orchardgrass. We did this under the assumption that with all other factors being equal, plants that had the greater photosynthetic rate would have the greater yield or potential for yield. Also, there would be no messy inter-specific sex problems as one might encounter among widely divergent genera or species (the "Atriplex" type is not ubiquitous). From our screening of numerous genotypes for NCE rates, we identified plants that consistently differed. These plants were examined for yield, leaf characteristics, and a number of other attributes. To make a long story short, we have concluded that the photosynthetic potential of a leaf is seldom fully realized, and that we must look at other energy transforming processes along with photosynthesis.

Light is not only essential as the energy source but spectral composition of light regulates numerous plant processes. Both quantity and quality will be varied as an approach to creating variation in growth and growth processes. This will provide opportunities for identifying processes that limit conversion of light energy, and this approach will supplement work in the laboratory by Drs. Chatterton, Schaeffer, and Tanada.

ARS PHOTOSYNTHESIS WORKSHOP

Urbana, Illinois (Illini Union)
January 21-23, 1975

James R. Cavanaugh

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I. Need for Chemical Research on Photosynthesis

We at the Eastern Regional Research Center (ERRC) feel very strongly about the need for a broad, balanced program in research on photosynthesis. We are not currently doing research on photosynthesis nor possess expertise in this field. Yet we recognize that photosynthesis lies at the very heart of all agricultural processes and represents the very basic reaction upon which all of agriculture is founded. It would seem not only appropriate but imperative that photosynthesis occupy a very central position in the agriculture research picture.

ERRC scientists are intensely interested in a vital role in that central picture. The kind of role we most wish to play is chemical and biochemical in nature. We are primarily a chemistry laboratory in both orientation and interest. It is in the photochemical, chemical, and biochemical areas of research on photosynthesis for which we have the greatest interest, to which we can contribute our best expertise, and in which we can make the most significant contributions.

New research directions on photosynthesis with promise of significant accomplishments are currently being envisioned in the fields of plant biology, plant genetics, and plant biochemistry. The possibility of enormous progress in traditional agriculture can be attained by these research approaches. Simultaneous with these kinds of research, we envision research along the photochemical, chemical, and biochemical directions. Progress in this direction will fulfill a three-fold objective. First, information developed at the molecular level on the

fundamental photosynthetic processes will provide vitally needed input to plant bioscientists in order for them to achieve maximum agricultural productivity along traditional lines. Second, knowledge developed will give us the ability to manipulate and control system variables, process parameters, product selectivities, and output productivities along non-traditional lines. Tailormade agricultural processes with regard to product desired, environmental conditions imposed, and selected productivity, could become viable alternatives. For example, selection of product sweetness and size, length of growing season, and toleration of ambient temperatures, could be achieved through physico-chemical modification or treatment. Third, chemical and photochemical knowledge of photosynthesis will enable us to construct and build artificial systems that duplicate agricultural processes and to adapt agricultural processes to other kinds of chemical production.

What is envisioned here is the production from the renewal resources CO_2 and H_2O of chemical systems, including ones vital to human nutrition, entirely through the use of solar energy. Imagine, if you will, fields "planted" with beds of catalytic materials of enormously complex chemical construction, supplied only with water and exposed to solar radiation and atmospheric CO_2, and through which percolate the desired chemical products of preselected design to be collected and pumped back through a network of underground conduits. The system is pollution-free, capable of construction anywhere on the globe which receives sunlight, and for which the cost of raw materials is practically negligible. Futuristic science fiction, based on experiments we envision today.

II. Research Approaches

It is proposed that research on photosynthesis be initiated at the Eastern Regional Research Center along two lines. The first would be on the exploration and investigation of the photochemical and chemical reactions and of the transport mechanisms that occur at the molecular level. These start with the capture of a photon and end with the production

of O_2 from H_2O and the transfer of protons to CO_2. Even a most cursory glance at what is already known about these fundamental processes reveals a wealth of complex and interrelated photochemical, chemical, and biochemical reactions. We are not yet at the stage where we could even pinpoint those specific areas of research which would be most useful and productive for us to undertake. To develop this kind of information would represent a commitment of funds and personnel. But, in view of our general expertise in chemistry (including organic, biochemistry, physical chemistry, and analytical chemistry), we recognize that this is the general area we should be in.

The second line of attack is to develop artificial systems based on the *in vivo* photosynthetic one. We propose to study photochemical reactions at the surfaces of supported catalysts and in thin films. Included would be the study of the photochemical reactions of light-absorbing dye molecules bound to silica surfaces or other support surfaces and the energy transport to the surrounding medium. Knowledge gained from primitive systems such as these would form the basis for the construction of more sophisticated and complex systems that mimic the photochemical reactions taking place within the chloroplasts of plant cells. Knowledge enabling the construction of artificial agricultural systems would ultimately be derived from research studies of this nature.

The first step in implementing a plan such as outlined here would be to develop the necessary expertise. What is envisioned is on-campus training of one or two of our scientists with outstanding scientists of the field. After six months or a year of training, these scientists would then be in a position to locate specific productive areas of research and to initiate detailed research proposals. Additional expertise would be both recruited from outside and developed from within. It is anticipated that the level of effort would grow annually as increasing demands on resources are made in order to achieve the long-range objectives.

III. Summary

Scientists at the Eastern Regional Research Center have an intense interest in and possess the necessary background expertise for research in the photochemical, chemical, and biochemical areas of photosynthesis. The demonstrated capability of scientists at the Center in chemical research indicate that significant contributions and accomplishments could be made. Therefore, we propose to initiate a major effort in photosynthesis research aimed at the elucidation of the underlying photochemical and chemical processes and the development of artificial agricultural systems. It is anticipated that this Workshop will help us to achieve the first step towards the attainment of these goals.

CONCEPTS OF CURRENT PROGRAM
Presentation for Photosynthesis Workshop
Urbana, Illinois Jan. 21-23, 1975

N. Jerry Chatterton
Light and Plant Growth Laboratory
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Two current, but to some extent opposite, hypotheses exist concerning the major limiting physiological factors of crop productivity. The theory is held by some that the photosynthetic production of fixed carbon (the source) is a limiting factor. Others theorize that the demand for assimilates (sink size) is a limiting factor. On the one hand experimental evidence shows that, if the photosynthetic rate is increased via atmospheric CO_2 enrichment, yield is increased. Symbiotic nitrogen-fixation, a process highly dependent upon photosynthesis as an energy source, is also greatly increased with CO_2 enrichment. Such relationships suggest the source as a limiting factor. On the other hand evidence suggests that during certain periods of physiological and morphological development the photosynthetic rate of many plants temporarily increases above its normal rate. Furthermore, if the sink/source ratio is increased photosynthesis increases also. These latter relationships suggest that many plants normally operate below their photosynthetic potential even under normal environmental conditions. More efficient use would be made of the resources available to the crop if more of the photosynthetic potential already present in the plant was used during a greater portion of the time.

The question must be asked: Why is the photosynthetic rate and production of some plants increased by CO_2 enrichment which results in an increased supply of assimilates when, on the other hand, an increase in sink size will also increase photosynthesis under atmospheric CO_2 concentrations? It appears that the source is limiting because growth is increased by increasing photosynthesis through CO_2 enrichment. Yet under normal CO_2 concentrations the sink appears limiting because photosynthesis increases when the source/sink ratio is decreased by increasing sink size.

Inasmuch as CO_2 enrichment is not presently practical under field conditions we have chosen to concentrate our efforts on the problem as it appears under atmospheric conditions. We have made the assumption, based on data from the plants we work with, that these plants have a significant amount of photosynthetic potential that is seldom expressed. The problem then becomes one of unleashing the potential that is already present in the plant so that the photosynthetic rate more nearly approaches its potential during a greater portion of the time.

Obviously, crop productivity is as dependent upon the translocation and utilization of photoassimilates as it is upon their initial synthesis. The daily accumulation in leaf tissues during illumination and a subsequent translocation of photoassimilates out during the dark period indicates a faster rate of assimilation than of translocation. Recognizing the

possibility that the accumulation of photoassimilates may, in an undefined manner, be exerting a feed-back type inhibition on photoshynthesis, we thought it important to ask why assimilates accumulate in the photosynthetic tissues during illumination. What is limiting translocation?

Since translocation of assimilates is highly dependent upon a readily available energy source we though that ATP-adenylate energy charge might be a starting point. Preliminary results now suggest that adenylate energy charge may be inadequate to meet the vein-loading energy requiring steps of translocation. The least we can say is that ATP-energy charge in the leaf declines concomittently with the daily increase in photoassimilate concentration.

We suggest the hypothesis that a lack of sufficient ATP-energy charge results in the daily aqcumulation of assimilates in photosynthetic tissues during illumination. Furthermore, the influence of a strong sink in effecting more rapid translocation and in stimulating photosynthesis may be through a system that turns on the ATP generating process to provide the additional energy charge at the required sites.

Are we asking the right questions or taking the correct approach if we are trying to increase the photosynthetic potential? Maybe we should be asking: How can we develop a plant that is "turned on" more of the time? The difference in the two questions may not be apparently great but the approach to the two ends may be entirely different.

E. H. Coe, Jr. | Photosynthesis-related Research with Corn

Chromosomal and extrachromosomal genes determine components of development, growth, form, metabolism and physiological efficiency. They can be manipulated with genetic knowledge, tools, and skills, some fully developed, some in need of further development, some currently unfolding and some as yet unexplored. This research program includes studies on chromosomal genetic systems and the development of genetic tools; studies are being initiated currently on the inheritance systems of the energy-transducing and storage organelles.

Questions: Are the plastids (and mitochondria) inherited entirely through the maternal parent? (We do not have an unambiguous answer for corn or for most other plants).

Are the organelles mixed or uniform in genetic type? (We lack methods and criteria by which this can be tested).

Are the organelles genetically interdependent with each other? (We lack methods and criteria).

Are all of the vital or limiting components of the plastids coded in the nucleus? (Experimental studies are limited).

Is <u>any</u> functional molecular property specifically determined by the organelle genome? (We apparently do not have a satisfactory answer in higher plants).

Approach: Survey groups of strains having distinctive cytoplasmic origins, in combination with a group of nuclear genotypes, for variations in proteins specific to their organelles. Prepare organelle samples of high purity; dissociate and/or fractionate; electrophoretically separate, and stain for proteins. Upon finding distinctive properties, test their inheritance pattern to determine whether uniparental inheritance or other confounding genetic mechanisms are involved; seek bases for exploitation and manipulation of the inheritance mechanisms. In the course of the study, nucleus-determined variation in proteins of the organelles should also be recognizable; these variations will be prime materials for analysis of major functional constituents of the organelles, and should give leverage toward genetic manipulation of limiting components.

These studies would be facilitated by simple, standardized methods for isolation and characterization of high-purity organelle preparations. Screening of the material for variations in protein primary structures by use of enzymatic and other functional criteria is not presently comtemplated because we lack the skills and instrumentation.

Exploitation of existing mutant types and other nucleus-determined variations will be most effective through collaboration involving coordinated work in genetics, ultramicroscopy, plant biochemistry, enzymology, physiology and biophysics.

SUMMARY OF RESEARCH RELATED TO IMPROVING PHOTOSYNTHETIC EFFICIENCY OF CROP PLANTS

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The two major concepts discussed in this presentation are:

(1) Control of photorespiration by C-3 plants

(2) Photosynthetic efficiency of chlorophyll mutants

Vigorous C-3 plants with potentially high rates of photorespiration are probably able to compensate for energy losses occurring by way of the glycolate pathway through regulation of glycolate oxidase. One of the endogenous substances which may be a candidate for this regulatory process is chlorogenic acid, a ubiquitous component of green tissues. Although chlorogenic acid stimulates tobacco glycolate oxidase *in vitro*, an interesting aspect of this interaction is that at 35 C the *in vivo* conversion of glycolate to CO_2 is suppressed by chlorogenic acid, whereas at 10 C and 25 C the conversion is stimulated. Thus, it would appear that the cofactor effect exerted by chlorogenic acid on glycolate oxidase is temperature dependent in a qualitative sense. The mechanism for this process is not known.

Although chlorophyll deficiencies would be expected to be detrimental to photosynthetic productivity, this expectation is not realized in yellow-green mutants. Various types of yellow-green mutations have been found in a number of important crop plants. It has been shown that most of these mutants are photosynthetically more efficient than the normal wild types and are characterized by aberrations within the chloroplast lamellae ultrastructure. A yellow-green mutant of tobacco, Pale Yellow (Py) does not exhibit irregular lamellar structure, but instead, gives evidence of a fragile chloroplast envelope. When fractionated, Py chloroplasts tend to break more readily than those from normal green plants. In addition, photosynthetic rates, including photophosphorylation, are greater with Py chloroplasts. These results correlate very well with the greater vegetative vigor of Py plants grown under favorable environmental conditions. On the other hand, several photosynthetically involved enzymes, eg. glyceraldehyde-3 phosphate dehydrogenase and ribulose 1,5-diphosphate carboxylase are invariably less active in Py plants. There is some evidence that the ratio of carotenoid pigments is different in Py leaves from that of normal green tobacco, but this situation has not yet been adequately explored.

Two immediate objectives suggested by the research results described in the foregoing are: 1) To characterize more fully the interaction of chlorogenic acid with glycolate oxidase and relate it to *in vivo* photorespiratory control and 2) To investigate various metabolic aspects of the photosynthetic efficiency of Py mutants to determine whether aberrant chloroplast structure is solely responsible for the vigor of these plants or whether other mechanisms are also involved in this phenomenon.

As to the more distant future, there appear to be only two or three general methods to exploit in a practical way information derived from fundamental photosynthetic research. One is genetic, by breeding and selecting more efficient plant lines; a second is chemical, by spraying or otherwise applying growth regulators that promote photosynthetic efficiency; and a third more remote possibility is environmental, by controlling more effectively than heretofore the external physical restraints on crop productivity.

Increased Photosynthetic Efficiency of Plants through Yellow Chloroplast Pigments

Herbert J. Dutton

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The objective of the CRIS Research Unit No. 3102-12340-001 of the above title is to increase the light absorption and photosynthetic capacity in green and yellow regions of the sun's spectrum through carotenoid sensitized photosynthesis and the associated enzyme systems. The approach of this project is to study the quantum efficiencies or action spectra for photosystems I and II in selected algae and to establish the photosensitization activity of specific carotenoid pigments. Amperometric determination of oxygen and fluorometric measurements of chlorophyll a *in situ* are anticipated as indices of photosynthetic efficiency and energy transfer, respectively. If yellow carotenoids and other nonchlorophyll pigments of algae, and later of higher plants, are found active in photosynthesis by using the green, yellow and orange light otherwise lost to the plant, then a basis for improving overall efficiency of photosynthesis is indicated; plant breeders may have a basis for selecting olive-green variants in order to obtain improved energy capture and higher yields.

This physical-chemical approach to the study of the primary reaction of photosynthesis has its continuity and historical basis in papers whose reviews in the recent text entitled "Photosynthesis" by Eugene Rabinowitch and Govinjee (John Wiley and Sons, Inc., 1969) follow:

1. Carotenoid-Sensitized Photosynthesis in the Diatom Nitzchia closterium, Amer. J. of Bot. 28(7): 516-526 (1941). Dutton and Manning. Since 1940, however, more reliable measurements first made by W. M. Manning and H. J. Dutton and coworkers at the University of Wisconsin and then by Robert Emerson and coworkers (first in California and then at the University of Illinois) brought general confirmation." (p. 142).

2. Chlorophyll Fluorescence and Energy Transfer in the Diatom Nitzschia closterium, J. Phys. Chem. 47(4): 308-313 (1943). Dutton, Manning and Duggar. "The first relevant observations were made in 1943 by H. J. Dutton, W. M. Manning and B. M. Duggar at the University of Wisconsin. They measured the yield of fluorescence of chlorophyll a in the diatom using monochromatic radiation and found that this yield was almost the same whether incident light was absorbed by chlorophyll a or by fucoxanthol. Subsequently C. S. French and coworkers in California and L. N. M. Duysens in Utrecht in the Netherlands found a similar transfer goes on...." (p. 157).

3. Chromatic Adaptation in Relation to Color and Depth Distribution of Freshwater Phytoplankton and Large Aquatic Plants, Ecology 25(3): 273-282 (1944). Dutton and Juday. "In algae living under the sea, deficiencies in chlorophyll as a light absorber become critical because light reaching these organisms is filtered through thick greenish blue layers of water. Plants living under these conditions have evolved auxillary pigments to absorb green light." (p. 117).

In current research, a spectrophotofluorometer has been loaned and has been modified for two light experiments and for measuring simultaneously fluorescence and oxygen evolution. Data acquisition and processing by an on-line computer is planned to facilitate the obtaining of action spectra for photosystems I and II. Through our Fermentation Laboratory, green, blue-green, red, and brown algae are acquired and being maintained. Chlorella pyrenoidosa and Nitzschia closterium are currently being grown in suspension culture.

In the future two directions of research will be taken if present studies on the role of carotenoids are encouraging: (1) Basic research is on the mechanism of carotenoid sensitized photosynthesis with monochromatic laser beam flashes of light. In addition to oxygen evolution, fluorescence, and CO_2 absorption, cytochromes, riboflavins and other indicators of kinetics and oxidation reduction potentials within the cell should be monitored in these millisecond experiments. (2) Applied studies on the plants of economic value, e.g., soybeans, corn, flax, will be initiated in cooperation with ARS geneticists, they supplying genetic variability in pigment systems and NRRC the photosynthetic efficiency evaluations. This has been discussed with ARS and University scientists on the nearby University of Illinois campus.

Contacts with academic research institutions have been reestablished in the past year, particularly with C. S. French (retired) and now Winslow Briggs, Director, Department of Plant Biology, Carnegie Institute of Washington on the Stanford Campus, California, with Professor Govindjee, Associate Director, Department of Botany, representing the Illinois

Photosynthesis Group formerly with Robert Emerson and E. Rabinowitch, Melvin Calvin, and J. A. Bassham, Biodynamic Laboratory, University of California, Berkeley, California. Pierre Joliet, Biophysical Laboratory in Paris and L. N. M. Duysens, Netherlands, who so successfully followed the lead of the thesis researches listed above. A "sabbatical leave" is planned for the project leader in the coming year to study photosynthesis in one of the above named laboratories. A 1975 postdoctoral research associateship in photosynthesis is being offered by ARS in association with the National Research Council and will be located at NRRC.

Full implementation of research on photosynthetic efficiency is presently limited by funds for equipment purchase in order to support the modern instrumentation needed for modern research on the photochemical aspects of the primary photosynthetic reaction. Lasers and other high intensity sources, high intensity monochromators, diffraction filters, sensitive and responsive (short rise time) detectors, amplifiers and other electronics will be needed to complement the present instrumentation. Fortunately much of the needed equipment purchased for other projects can be made available for loan by various Laboratories of the NRRC. While this equipment is not what one would have chosen first for photosynthetic research it does suffice for the initial experiments planned. Some interfaces to the on-line computer are available; others needed must be acquired. Adequate computer expertise both in computer hardware and software is available. In the expansion of this interdisciplinary research whose

name is photosynthesis expertise in physics and electronics will be needed as well as that photo-, bio-, and microbiological-chemistry. Space is generally adequate even though NRRC's excess laboratories have been rented to APHIS's National Pesticide Laboratory. Present personnel assigned: Dr. H. J. Dutton, Dr. K. E. Eskins.

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Crop varieties currently available are often limited from the production of their full yield potential because of environmental stress (fertilizer, moisture, temperature, etc.) at some period of growth. Much of the stress could be eliminated by use of adequate fertilizer, effective herbicides, and appropriate cultural practices. Moisture stress cannot always be eliminated, but irrigation is being used more widely and many areas of the Corn Belt often receive adequate rainfall. Hence, we would like to be able to develop new hybrid corn varieties with greatly increased yield potentials under optimum growing conditions and the ability to give high yields even under stress.

In our cooperative program at Ames, a breeder-physiologist, a physiologist, and a pathologist from Iowa State University are working as part of the team for corn improvement with the ARS breeders and entomologists. Because photosynthesis involves both rate and time, we have devoted our initial efforts concerning photosynthesis to increasing the time of the grain filling period. Greater cold tolerance (an increased rate of emergence and growth under cool soil temperatures) and decreased photosensitivity to day length should permit early planting and earlier tasselling so that we can select varieties with a longer grain filling period.

The necessary models have been developed for quanitative traits (traits controlled by several loci and influenced by environmental conditions) to permit us to plan more effective breeding programs. We have found that we must improve random mating breeding populations (open-pollinated varieties) so that we can extract inbred lines for improved hybrids from the improved breeding populations.

Great improvements in the breeding populations have been made for any character in which a satisfactory evaluation technique has been developed to handle large numbers of plants -- stalk rot resistance, European corn borer leaf feeding, etc. Until recently we had been using only yield per se as an integrating index for improving crop growth. The Iowa State breeder-physiologist has shown that percentage emergence and 5-week dry weight for corn lines planted in late March or early April will provide selection criteria for cold tolerance, and we have added this technique to our selection program. The development of equipment and techniques to measure photosynthesis of detached leaves from a large number of plants is underway. We want to determine the amount of genetic variation for the rate of photosynthesis in our breeding populations and the relationship of photosynthesis with yield under optimum environmental conditions before we initiate any recurrent selection programs for increased rates of photosynthesis.

When we selected for yield per se, improved populations and hybrids were developed with 25 to 30% higher yields. Preliminary evaluations indicate that the yield increase was due primarily to decreased barrenness under stress or to an increase in number of ears per plant under favorable environmental conditions. Further comparisons are planned to evaluate changes in plant morphology, length of grain filling period, and rate of photosynthesis as far as possible with the limited funds now available.

Utilization of plant physiology research for improving crop yields will be greatly enhanced by the cooperative and comprehensive team approach on a specific crop as is the situation on sorghum at the University of Nebraska, soybeans at the University of Illinois, etc. If funds and staff positions become available to support increased ARS research on photosynthesis, operating funds of existing centers might be increased and cooperative teams might be developed on other important crops such as corn.

Photosynthesis Workshop Presentation

C. D. Elmore

My Cris title is Production, Distribution and Utilization of photosynthate in the cotton plant. This title is rather broad and as such encompasses a number of subject areas of which photosynthesis *per se* is only one. At the time I started on the job I decided that an area that required further work which was included within the scope of this title was the distribution or translocation problem. I find that this topic is currently quite popular among researchers. At least the relevancy of translocation to the study of photosynthesis and to yield of crop plants is now more widely recognized than it was in the past.

There are several ramifications of the co relation of photosynthesis and translocation that bear discussing. Some of these are in the following list.

1. Photosynthesis and translocation.
    a. Photosynthesis and starch accumulation in the chloroplast.
    b. Translocation and starch accumulation in the chloroplast.

2. Phloem loading.

3. Phloem unloading.

4. Other source sink aspects.

My current research is directed to investigating some of the more basic problems in phloem translocation, eg. native phloem mobile compounds, concentration of these in the phloem, total mass transfer rates, etc. I feel that questions of this nature are important for a total understanding of the problem of dry matter accumulation. Problem areas, research opportunities and research needs as I see it in my area of study are these: (1) We need a definite understanding of the mechanism of phloem loading and unloading (2) The "feed back inhibition effect" of photosynthate on photosynthesis and translocation should be fully investigated (3) The site of reduction of nitrogen for developing fruit or seed should be determined. That is where does the energy required for NO_3 reduction come from.

These problems have only a peripheral bearing on photosynthesis. I think it is quite necessary that basic research on phloem translocation be conducted by ARS. And I for one will continue to do my part. At the same time I think the area of photosynthesis could profitably include more SMY's on basic aspects. Here I would include the light reaction in general, chloroplast composition and structure (mutants would be useful for this), and enzymology. We must not reach for quick results without investing some research dollars in long range basic goals. To do so could have far reaching detrimental effects on our efforts to supply the world's food needs in the future.

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My research deals with increasing productivity of native and introduced grass species in the Northern Great Plains. The physiological phase of this project was initiated in June 1974. I work very closely with a geneticist (Dr. Reed Barker) who works on forage grass varietal development. Our research approach is to ultimately determine the physiological basis for yield expression in forage grasses, locate sources of variation, and finally exploit these sources to increase productivity. In the Northern Great Plains, we receive about 15 inches of precipitation annually. Thus, plants are generally growing under considerable water stress for extended periods of time. Therefore, in our research program we are keying on photosynthetic potential and plant water relationships and the interaction of these two processes in range grasses.

Research on improving photosynthetic efficiency in grasses under field conditions probably can be obtained most permanently through genetics. Thus, we feel that determining the physiological basis for yield differences and utilizing this information in a breeding program should greatly enhance the opportunities for development of superior forage grass varieties.

Some of the processes that we are going to look at and hopefully which will provide useful information for improving productivity are as follows:

a) Photosynthetic efficiency: We need to find ways to measure actual photosynthetic potential in grass species, examine genetic variation, and then incorporate the selections with high photosyntheses into a germplasm pool for varietal development.

b) Water use efficiency: Examine variation in WUE in grass species. To obtain an acceptable WUE we may have to settle for a less than maximum rate of photosyntheses due to the regulating effect of the stomates on both processes.

c) Water stress: Species response to moisture stress will be important in determining productivity under dryland.

d) Environmental factors: Species response to light intensity, CO_2 concentrations, air and soil temperature.

e) Diffusive resistance to carbon dioxide and water vapor: Determine species variation for stomatal and mesophyll resistance to CO_2 diffusion and stomatal resistance to water vapor diffusion out of the leaf.

If a physiological factor is found to be highly correlated with productivity, procedures will have to be developed to mass screen plants. In many ways, depending on species variation, developing screening methods may prove to be the limiting step in utilization of physiological processes in development of superior forage grass varieties.

Photosynthesis-Related Research

Gene Guinn[1]

My research program has been concerned with factors that control abscission of cotton squares (flower buds) and bolls (fruits), and has been concerned with photosynthesis only indirectly. We found that factors which decrease net photosynthesis caused increased rates of ethylene evolution by young bolls and caused increased rates of abscission.

We also found that moisture stress caused ATP concentration in leaves to drop to very low levels. I feel that a more detailed investigation should be made of the effects of moisture stress on photophosphorylation. For example, is there a threshold level at which moisture stress affects ATP? Can the plant adjust to moisture stress, if it develops gradually, so that there is less adverse effect on photophosphorylation? Does ionic status of the plant affect sensitivity of photophosphorylation to moisture stress? With depletion of groundwater supplies and increasing salt content of irrigation water in some areas, and the current drought in parts of the world, a more thorough understanding of the effects of moisture stress on photosynthesis is needed.

I have also been interested in factors that control starch synthesis and breakdown. This subject could be quite important if starch accumulated in chloroplasts inhibits photosynthesis. We need to determine

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whether starch in chloroplasts does inhibit photosynthesis and, if so, at what level. We found that exposing cotton plants to 1,000 ppm CO_2 in maximum sunlight conditions caused large accumulations of starch in leaves and greatly decreased their ATP content. Perhaps starch in chloroplasts, like moisture stress, inhibits photophosphorylation. If starch does inhibit photosynthesis, this inhibition might explain the observed effect of sinks in stimulating photosynthesis. In other words, the stimulation of photosynthesis by sinks may actually be due to relief from inhibition because the sinks compete with starch synthesis for available sugars and, thus, prevent starch from accumulating to inhibitory levels. Inhibition of photophosphorylation by moisture stress or by starch could also contribute to the "mid-day slump" in photosynthesis.

We know that moisture stress decreases starch levels in cotton leaves, but we don't know why. There are two obvious possibilities: (a) starch degradation is promoted or (b) starch synthesis is inhibited. We are currently investigating the effects of moisture stress on amylase activity in cotton leaves. On the basis of the effects of moisture stress on abscisic acid (ABA) levels in plants and the effects of ABA on amylase synthesis in the barley aleurone, one would expect that moisture stress should decrease, rather than increase, amylase synthesis. It is possible that ethylene, which increases with moisture stress, may cause an increase in amylase synthesis or activity. Another possibility is that a decreased level of ATP affects synthesis of starch. This could be a direct effect because ATP is required for formation of ADP-

glucose in starch synthesis, or it could be indirect through control of enzyme activity. Many enzymes that require ATP are strongly influenced by energy charge; they are activated by a high level of ATP and inactivated by a low level of ATP. They may also be inactivated by high levels of AMP and inorganic phosphate. Therefore, if moisture stress inhibits photophosphorylation, the resulting low level of ATP and high levels of AMP and inorganic phosphate may inhibit or inactivate enzymes responsible for starch synthesis. If starch in chloroplasts inhibits photophosphorylation the feedback control for limiting starch synthesis may operate through this inhibition which, in turn, would limit the production of ATP and glucose required for starch synthesis. Unfortunately, other metabolic processes that require ATP would also be limited. Thus, it is important that we learn more about the effects of starch on photosynthesis and more about the control of starch synthesis and degradation.

PHOTOSYNTHETIC RESEARCH IN AGRICULTURE

J. D. Hesketh

These comments are meant to replace a provocative speech I prepared for handout prior to the workshop. In the earlier version, I worried about the example photosynthetic modeling has set for the effort underway to model whole plant physiology. After I returned from the workshop, Park Nobel's new book "INTRODUCTION TO BIOPHYSICAL PLANT PHYSIOLOGY", W. H. Freeman and Co., San Francisco, came in and it has a very innovative chapter on gas exchange-transport processes in the leaf. This new book, along with the one by Milthorpe and Moorby (INTRODUCTION TO CROP PHYSIOLOGY, Cambridge Univ. Press), seem to squelch my doubts about the immediate future of plant modeling activities.

The list of papers cited by my colleagues at the workshop seemed rather impressive, especially those from W. Ogren's and Jim Pallas' laboratories. Both gentlemen have taken advantage of post-docs; hopefully we will see more of this in the future as a result of this workshop. There seemed to be numerous young, technically competent ARS scientists who obviously will do the innovative research of the future, if they weren't too vocal at the workshop.

Our group at Mississippi State includes four engineers with the mission of developing computer models for eventual inclusion in farm-ecosystem management models. We have worked on photosynthetic models from time to time; however, our main contribution has been in the development of (computer) techniques for studying whole plant systems and the role of photosynthesis in relation to other plant physiological processes in determining growth or yield. Some of this work has been done with Jack Mauney's group.

I recently attended an international symposium on photosynthesis, along with Ogren and Bjorkman. Frontier research underway was discussed there in depth. Techniques for study of the physical aspects of the light reactions seemed to have been incorporated into gas-exchange research. Also, there were papers on photosynthesis in relation to translocation, floral initiation, water stress, hormone physiology, and modeling.

My own recent contributions to photosynthetic research were greatly enhanced by collaborations with R. Alberte, G. Hofstra, J. Jones, J. McKinion, H. Lane and A. C. Thompson, as well as the group at the Western Cotton Lab. All this has involved cooperation on an equal basis outside any chain-of-command; studies need to be made as how to create environments conducive for this kind of team research. Some travel may be required. Young scientists seem to work alone productively for awhile, then they develop ties with other scientists. L. T. Evans at Canberra was quite successful at this for awhile.

It is my feeling that the ARS should press on with the type of research that W. Ogren and others are doing at the chemical level. Agriculturalists expect us in the space age to apply the most sophisticated techniques available to agricultural problems. Scientists who start working at this level usually progress quickly to the kinds of research most of us are doing, but such scientists have a much better background. The development of such scientists should be fostered within the system.

Report to ARS Photosynthesis Work

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I. Accomplishments of Microclimate Research

A. Completed about 20 years of intensive research on micrometeorological influence on crop photosynthesis.

B. Studied in detail radiative transfer with crop canopies and have documented these processes.

C. Studied aerodynamic processes of crop canopies and have documented the nature of the atmospheric transfer properties.

D. Have compiled data on the vertical profiles of air temperatures, water vapor, and CO_2 concentration within and above crops.

E. Made extensive calculations of the short term exchange of CO_2 and water vapor above crops.

F. Attempted to alter microclimate of crop to improve crop CO_2 assimilation by altering crop structure and erecting shade cloth.

G. Developed and tested soil-plant-atmosphere model (SPAM) to study further the influence of the microenvironment on CO_2.

II. Conclusions Relevant to Photosynthesis

A. Instantaneous and cumulative environmental variables have a significant influence on crop assimilation rate. Particularly in the development of plant stress which limit CO_2 assimilation.

B. Except for radiation, micrometeorological processes have little effect on the CO_2 assimilation rate.

C. The radiation effect on CO_2 assimilation is closely linked to the crop structure, particularly total leaf area. Significant improvement of photosynthesis through radiation manipulation doesn't seem likely.

D. The greatest controls of CO_2 assimilation under field conditions are at the physiological level. From model analysis the most significant variables seem to be stomata and mesophyll resistance.

III. Future Research Relevant to Photosynthesis

A. Examine the variability of stomata and mesophyll resistance among soybean genotypes.

B. Examine the dynamic characteristics of stomata and mesophyll resistance under field conditions.

C. Genetic manipulation of stomata and mesophyll resistance to improve crop water-use efficiency.

D. Genetic manipulation of stomata and mesophyll resistance to improve crop photosynthesis.

E. Can increased photosynthesis by soybeans be translated to increased seed yield?

Photosynthetic Efficiency Research

Western Cotton Research Laboratory

Report by Jackson Mauney

The major research effort of the physiologists at the Western Cotton Research Lab. is to elucidate the effects of environment on productivity of the cotton plant. A portion of this effort is directed at the effects of hormones and nitrogen metabolism. The projects of Drs. Guinn, Chang, Fry, and myself all have an interest in the effects of environment in photosynthetic efficiency. Dr. Guinn's project will be reported by himself.

Dr. Fry as well as Dr. Ehrler at the U. S. Water Conservation Lab., Phoenix are concerned with water use efficiency, defined as the ratio of dry weight accumulation to water used. Dr. Ehrler has surveyed typical desert species and found only a narrow range in this ratio. Dr. Fry has found that yield of cotton is inversely related to the water stress during peak flowering of cotton. While neither of these observations applies directly to photosynthetic efficiency during water stress, it is clear that in order to maximize photosynthetic productivity these species must be grown with adequate water.

Others in the Phoenix group are addressing the problem of what physical and metabolic factors limit yield of cotton. As a tentative hypothesis we have looked into the build up and breakdown of starch reserves as the limiting step in converting photosynthate into harvestable yield. One aspect of this problem was studied by Dr. Richard Jensen of the University of Arizona under a grant from our laboratory. Using

separated cell suspension from cotton leaves he found that starch synthesis was sensitive to concentration of precursors in the suspending medium but that starch breakdown was not responsive to metabolite concentration. Dr. Chang in the Western Cotton Lab., is now studying the chemistry of leaf storage starch in cotton and the enzymes associated with its deposition and remobilization. This will give us some of the necessary background to decide why net accumulation rates are not as great in cotton as the instantaneous photosynthetic rates indicate they should be.

My own work recently has been to develop a technique for measuring specific leaf weight as an index of photosynthetic activity which is simple, and adaptable to field situations. With cotton leaves the weight of leaf discs fulfills these requirements. Using this technique we will measure photosynthetic accumulation under a variety of field conditions next season. This will be useful data, I think, for many purposes, not the least of which is the refinement of mathematical simulations such as Symcot II which are based on photosynthetic activity.

Inhibition of Photosynthetic Electron Transport and Photophosphorylation by Herbicides

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Our over-all research assignment is to identify mechanisms involved in the action and selectivity of herbicides at the cellular and molecular levels that are related to the expression of phytotoxicity. Investigations concerned with the effects of herbicides on electron transport and photophosphorylation in chloroplasts constitute only one phase of our studies. This work was initiated following reports in the literature in 1956 relative to inhibition of the Hill reaction by diuron (DCMU).

A large number of structurally diverse chemicals, some of which are herbicides, are now known to interfere with the Hill and associated reactions. Through the use of various electron mediators and partial reactions, it is possible to categorize inhibitory herbicides as (a) pure Hill inhibitors that have a single site of action associated closely with photosystem II; (b) uncouplers; (c) inhibitory uncouplers that act both as Hill inhibitors and uncouplers; and (d) acceptors of electrons from photosystem I (the bipyridyliums). To date, no herbicide has been shown to function as an energy transfer inhibitor. Those herbicides that have a site of action on the energy conservation pathway also inhibit oxidative phosphorylation in isolated mitochondria.

Of the many inhibitors of photosystem II, investigators have studied only the action of diuron in detail. Although the action of many other herbicides is compared frequently to diuron, sites of action have not been resolved beyond the general area around photosystem II. The mechanism through which inhibition is imposed, even by diuron, is unknown, Because of their structural diversity, it is unlikely that all of the herbicidal Hill inhibitors are affecting the same site in a common manner. However, there is little direct evidence to suggest that they do not do so.

We are attempting also to identify and determine the contributions of the chemical and physical properties of inhibitors to the expression of inhibition. Inhibitors must be able to penetrate to the active site and assume the precise spatial configuration required to complement the molecular architecture of the active center, and hence, to block the key reaction. Properties which could conceivably be of importance include partitioning characteristics (hydrophilic/lipophilic balance), steric relations (the ultimate attainable configuration), resonance, keto-enol tautomerization, cis or trans relation of the amide hydrogen and the carbonyl oxygen, and the possession of a critical charge by particular substituent groups that participate in the intermolecular interactions at the active centers.

A full comprehension of the specific sites involved in the inhibitory action of herbicides and the mechanisms through which inhibition is produced will be achieved only when the uncertainty is resolved relative to the sequence and interrelation of components in the electron transport pathway, numbers and locations of phosphorylation sites, and the mechanism involved in phosphorylation.

Insofar as they have been studied, all herbicides that inhibit electron transport of isolated chloroplasts also inhibit photosynthesis of intact plants and photosynthetic microorganisms. The Hill inhibitors have been shown to produce phytotoxicity only in the light and severity of the response is proportional to light intensity.

William L. Ogren
U. S. Regional Soybean Laboratory
Urbana, Illinois 61801

Work done in our laboratory suggests that rates of photosynthesis and photorespiration in soybean leaves are largely determined by the kinetic properties of ribulose 1,5-diphosphate carboxylase with respect to carbon dioxide and oxygen. A substantial increase in photosynthetic productivity can be expected from mutagenic or chemical modification of this enzyme so that carboxylase activity is increased and/or oxygenase activity is decreased. Current experiments are exploring ways to modify soybean RuDP carboxylase and to develop and perfect assays to detect enzyme modification in purified enzyme systems, isolated mesophyll cells, and intact leaves.

J. E. Pallas, Jr., Plant Physiologist

Increase the productivity and efficiency of the soil-plant-atmosphere system through further understanding of photosynthesis and physiologically related processes.

Situation evaluation:

The photosynthetic capacity of plants varies considerably amongst genera, species and apparently even some cultivars. Whether it be for food, fibre, forage or an energy storage system for the future, in most instances of southeast cropping, we are harnessing less than 2% of the suns potential power. This is a seemingly terrible loss of solar power; with impending food and energy shortages of the future photosynthetic research certainly needs a lion's share of agricultural scientists' attention.

In general photosynthetic potential is directly related to yield, this is most certainly true with most forage species but not necessarily true with crops where translocation and storage of photosynthate are of considerable importance. Ours and the studies of others have shown environmental factors may induce or reduce photosynthetic potential; also internal metabolism e.g. photo and dark respiration decreases photosynthetic efficiency. In most instances we do not have enough basic information concerning how environmental change changes photosynthetic rate. One of the most important edaphic environmental parameters is soil-water. Its interaction with yield potential has been little studied and thus is still little understood. It is this environmental interaction with photosynthetic potential that lends itself best to our research interests. Knowledge of soil-water and fertility interactions with photosynthesis certainly can be considered examples of high priority needs.

Besides studying the environmental and respiration feedback system, in our studies at the Southern Piedmont Conservation Research Center, we have recently identified an endogenous, circadian control of photosynthesis, seemingly working through stomatal operation. We know essentially nothing about this control, however, we speculate that it may minimize crop productivity under certain conditions.

Objectives of our photosynthically oriented research:

1. To more fully understand the interaction of environmental change on the photosynthetic rate of certain cropped species.
2. To characterize selected germ plasm of several important species cropped in the southeast as to its photosynthetic reactivity and potential as primarily tested under controlled environmental conditions (presently tomatoes and peanuts).
3. To measure and study certain parameters concerning this photosynthetic reactivity and potential i.e. diffusional resistances, especially stomatal.
4. To concentrate on studies in stomatal activity (e.g. anatomy, morphology, physiology and biochemistry) in order to more fully understand the stomate as an attenuator in the plants photosynthetic and plant water relations scheme.

Research Approach:

The major thrust of our photosynthetic research, thus, is to identify the controllable characteristics concerning photosynthesis and as to whether they be genetic and/or environmental intheir undergirding of the photosynthetic process; then to synthesize from this knowledge more efficient, higher yielding plants and production techniques. The species studied by us are primarily those showing highest economic return to the Southern Piedmont and its very closely associated areas.

Role of Photosynthesis Research in Weed Growth Studies

John R. Potter, Plant Physiologist
Southern Weed Science Laboratory
Stoneville, Mississippi 38776

Weed infestations in crops seriously reduce yield. Weeds not only serve as sinks for nutrients but they also physically occupy space in competition with crops. The relative rates at which plants grow is a primary factor in competition. I am trying to determine the influence of environmental variables on the relative growth rates (dry weight accumulation) of several weed and crop species. With enough information of this type, it should be possible to estimate growth under a wide variety of conditions and to determine if a species has the potential to become a troublesome weed under a given set of environmental conditions. The ability to estimate dry matter production of weeds could be useful in crop production models because weeds function as sinks for nutrients.

So far I have confined the problem to the growth of individual plants during the 4 weeks after emergence. I have worked or tried to work with plants which are not limited by plant-plant interactions; where each plant receives ample space for growth without interference from adjacent plants or containers. I think this is often the case in a field cropping situation during the first 3 or 4 weeks after seedling emergence.

The following are the questions I am trying to answer:

What is the effect of temperature on the rate at which several species (6 weed and 3 crop) grow in terms of dry weights of leaves, stem and roots as well as the rate of leaf area growth?

How does each species partition its dry matter production, and what effect does this have on the subsequent growth rate?

Does the growth rate correlate with rates of photosynthesis and respiration?

The first two questions involve growing plants in controlled environments and weighing and determining the area of the separate parts at different times after emergence. The growth dynamics will be described by the appropriate coefficients, and these coefficients should be characteristic of a species under a certain environment.

The third question involves measuring photosynthesis and respiration rates and trying to predict the growth dynamics on the basis of the gas exchange data. Here it is necessary to know the amount of photosynthate that a plant will invest in leaf production. This is one of the partition coefficients which must be determined. Photosynthesis and respiration will be measured by gas exchange from plants kept in controlled environments.

Dry weight accumulation of plants follows an exponential growth function during the first few weeks after emergence. Because growth is exponential, a delay of a day or so in emergence, or a lag in the development of photosynthetic competence after emergence could have a large effect on the dry weight at 3 or 4 weeks after emergence. Therefore I have attempted to measure the rates at which seedlings develop photosynthetic competence. Dr. W. P. Wergin, formerly at Stoneville, and I have tried to determine how fast the chloroplasts of emerging velvetleaf seedlings develop structurally as well as functionally. These studies include measurements of CO_2 exchange rates, chlorophyll and carotenoid accumulation, and characterization of chloroplast fine structure as a function of seedling age. These data should give an understanding of the events leading up to the onset of photosynthetic competence, and could reveal differences among species that allow one to become established more rapidly than another.

Another aspect of my program includes studies of herbicide action as it is influenced by the environment. Herbicides applied to control weeds often give unsatisfactory results, possibly because we do not completely understand how these materials interact with weeds and their environment. I am working with a compound, bentazon, which is a photosynthesis inhibitor. The action of bentazon, a promising new herbicide for control of broadleaf weeds in soybeans, is strongly influenced by light. Bentazon applied at the rate of 1/4 kg/ha to cocklebur stops photosynthesis within one hour. The subsequent toxicity depends on stopping photosynthesis, however, the lower the light intensity, the longer it takes for toxicity symptoms to develop. If the plant metabolized or translocated the herbicide before it had a chance to cause cell damage, eratic results could be expected. It should be possible to detect the presence of bentazon in the leaves by monitoring photosynthesis. Therefore one could follow the rate of entry of phytotoxic amounts of bentazon into the leaf from the leaf surface or from adjacent leaves. The role of stomata in the absorption process could be determined.

Here photosynthesis will be used as an indicator of the presence of bentazon. This technique has an advantage over using radioactive tracers because the presence of radioactivity does not necessarily mean that biological activity is also present.

A major problem in all this work is the need for growth chamber space with lights which approximate the intensity and spectrum of full sunlight. I don't know if a phytotron would overcome this problem, since the phytotron is subject to light reduction on cloudy days or short days. Studies done in growth chambers, even at 4,000 ft-c, have the advantage of being reproducible.

Photosynthesis Workshop
Bonnie J. Reger
Southern Weed Science Laboratory
Stoneville, MS 38776

I am responsible for conducting comparative physiological/biochemical studies of crop plants and their respective hard-to-kill weeds. This type research is intended to contribute to a better understanding of plants by determining fundamental differences between crop plants and weed species. This approach to weed research holds promising possibilities for the development of new weed control practices.

To date, my research efforts have dealt with weed seed dormancy and biochemical prerequisites to seed germination (radicle protrusion). However, photosynthetic carbon metabolism studies have contributed greatly to discerning differences between crop plants and weeds by categorizing them as C_3 or C_4 plants. I intend to initiate investigations in the general area of photosynthetic carbon metabolism.

Available information regarding C_3/C_4 weeds will be used to select weed species for the following investigations: (1) inhibitors of enzymes unique to C_4 weed species, eg. Pyruvate Pi dikinase and PEP carboxylase, will be sought to establish the feasibility of selective herbicides based on carbon metabolism and (2) C_3 weed species which appear to be exceptional C_3 plants based on their competitive abilities will be studied to determine physiological/biochemical factors contributing to their competitiveness.

ARS NATIONAL WORKSHOP - IMPROVING PHOTOSYNTHETIC EFFICIENCY OF PLANTS

10-minute Overview Presentation by F. W. Snyder January 1975

Sugarbeet Plant Characteristics

Indeterminate, vegetative plant, grows large taproot, accumulates sucrose in taproot over growing season. Seed weighs about 3.5 to 4 mg. Leaf area of newly emerged seedling is very small compared to many crop plants. Leaf area per plant doubles about every 3 days outdoors at East Lansing, MI. between May 25 and June 15 (mean temperature 17 to 20° C). Twenty-two days after emergence in the growth chamber, leaf area, leaf-blade weight, and taproot-hypocotyl weight of individual plants within breeding lines and hybrids may vary by 2- to 3-fold, and leaf-blade weight occasionally by 10-fold.

From Computer Modeling

Priorities for use of photosynthate in sugarbeet are Shoot > Fibrous roots > Taproot > Sucrose accumulation. Note the low priority for taproot growth.

Assumptions

1. More than half of the plant to plant variation in sugarbeet is genetically controlled.
2. Faster growth rates of leaves and taproot in seedling sugarbeets should result in larger plants after full-season growth.
3. A seedling plant that partitions relatively more photosynthate to the taproot should have a larger taproot after full-season growth.
4. During full-season growth, ontogenetic changes in growth rate follow similar patterns for fast-and slow-growing plants of a breeding line, but the patterns of growth might differ among breeding lines.
5. A community of plants selected for these new characteristics should outyield a community of plants selected by previously used criteria.

Concepts

Increase yield of sugarbeet by exploiting the source-sink concept as follows:

1. Increase the size of the source by selecting individual plants that accrete leaf area more rapidly - trap greater percentage of solar radiation - more rapid increase in LAI - longer LAD.
2. Increase size of sink. If the taproot would enlarge more rapidly, a) it would provide greater sink capacity with less chance that, under favorable conditions for photosynthesis, photosynthate might accumulate and suppress the rate of photosynthesis, and b) the taproot probably would grow larger in full-season growth.
3. Relation between source-size and sink-size can be quantified by calculating a ratio from the Sink-size divided by the Source-size. In this case,

$$\text{Growth-Partitioning Ratio (GPR)} = \frac{\text{Taproot-hypocotyl fresh weight}}{\text{Leaf-blade fresh weight}}$$

Approach

I am using allometric growth analysis of individual sugarbeet seedlings at about 22 days after emergence in the growth chamber. After weighing the plant parts and calculating the GPR, the remaining portion of a selected plant (consisting of the intact growing point, hypocotyl, and taproot free of fibrous roots) can be planted and it will grow. Seed can be produced on these selected plants after photothermal induction. Seeds from low- and high-GPR selections can be used in various studies.

Questions Needing Answers

1. Since selection pressure alters the GPR of sugarbeet, can we use progenies with extreme values of GPR to determine what mechanisms cause the differences in GPR?
2. What is the endogenous mechanism(s) that controls leaf accretion in the plant?
3. Can selection pressure alter rate of leaf accretion within sugarbeet breeding lines?
4. Will more rapid leaf accretion by the individual plant increase the full-season root yield of a community of these plants?
5. If we know the relative GPR values for seedlings of sugarbeet breeding lines, can we predict their root-yield potential when using these lines in making hybrids?

Program Inadequacies

1. Need a full time technician.
2. Will need help in determining heritability of these traits.
3. Will need help in determining mechanisms that cause differences in GPR.
4. Program could be speeded up if more growth-chamber space becomes available.

Opportunities

The sugarbeet seedling, as an intact system, offers some unique advantages for studying partitioning of photosynthate in a vegetative plant that remains free of the complications of the reproductive phase, yet has a large sink capacity in the developing taproot.

Overview of Photosynthesis Research by USDA-ARS and The University of Nebraska

Charles Y. Sullivan
Research Plant Physiologist
USDA-ARS, North Central Region
Lincoln, Nebraska

There is a cooperative team effort between the USDA-ARS and the University of Nebraska aimed primarily at the physiology of sorghum and its relation to yield and genetic improvement. Photosynthesis is obviously an important part of the total program, although the amount of time spent on research directly involved with photosynthesis has not been as great as it may be, or perhaps should be, in future research.

Grain sorghum yields are highest when the crop is irrigated or grown under conditions of adequate precipitation. However, most of the acreage of the crop is grown on dryland, usually limited in soil moisture availability during some part of the growing season, and quite often accompanied by high temperatures and high evaporative demand. Therefore, much of our attention has been focused on the effects of heat and drought stress on this crop, including photosynthetic activity. It has also been of interest to compare the responses of sorghum to other crops.

Since stomatal closure plays an important part in regulating transpirational loss of water and involves photosynthesis by effects on gas exchange, it has been important to us to define stomatal responses to environmental conditions. Evidence reported in the literature tends to support the concept that reduced photosynthesis with imposed water stress is due mainly to increased diffusive resistance resulting from stomatal closure. We are not convinced that is always true in the case of sorghum.

The activity of chloroplasts isolated from plants exposed to stress* or nonstress* conditions has been used to help resolve this question. Results with chloroplasts reported in the literature are not in agreement, although greater evidence seems to support the belief that photosynthetic reactions such as

the Hill reaction, photophosphorylation, NADP reduction, and some specific carboxylation enzymes are not significantly affected until severe water stress occurs. A few years ago we spent considerable time working with chloroplasts isolated from grain sorghum, and we also failed to find diminished activity of the Hill reaction, cyclic photophosphorylation and PEP carboxylase until very severe stress occurred. However, measurements of endogenous exygen evolution without added electron acceptors showed some marked differential varietal responses to modest, or sometimes low, water deficits, similar to that often obtained with intact plants. One difficulty with these experiments was that the rate of oxygen evolution obtained was very low compared to net carbon dioxide exchange in intact tissue. One graduate student did his thesis work on the limiting factors involved. He isolated and partially identified a pteridine consisting of a side chain, uronic acid and a peptide. Fairly high rates were obtained with chloroplasts suspended in a simple buffer when this factor was added in the proper concentration.

Unfortunately, chloroplast work has not continued recently in our laboratory, but the need is still there. If chloroplast techniques are mastered and results repeatable, this line of approach should contribute significantly to our knowledge of photosynthetic responses of diverse genotypes to environmental stresses, particularly because of the ability to precisely control the environment of the chloroplasts.

Chloroplasts also offer a means of investigating specific high temperature effects on photosynthesis. We have shown that there are marked genotypic differences in the photosynthetic response of sorghums to high temperatures. Varietal differences in stomatal closure also results in differential leaf temperatures. Some lines maintain photosynthesis near maximum levels with increased temperature while in others photosynthesis completely stops. These results suggest that considerable progress is possible in selecting for photosynthetic efficiency

in hot climates. Tolerance of photosynthesis to heat has also been positively correlated to true desiccation tolerance as evaluated by cellular membrane degradation, thus another implication that photochemical reactions also may be more tolerant to desiccation in the heat tolerant lines.

Recently we are attempting to investigate the effects of desiccation on the photochemical apparatus in intact tissue by inducing stomatal closure with high carbon dioxide concentrations and measuring cuticular oxygen exchange. The response is then compared to that obtained for carbon dioxide exchange with the IR gas analyzer at normal CO_2 concentrations.

Our results have also shown that while natural field drought had no significant effect on the Hill reaction by isolated chloroplasts, the thermal stability of the reaction was significantly affected. In several experiments drought effects were expressed as decreased thermal stability in sorghum and pearl millet. Researchers should be aware of interactions between environmental stresses and they need further investigation.

Plant acclimation, or hardening, may be as important in photosynthesis research as in research of other plant environmental responses. For example, experiments on the Hill reaction have shown that no reduction in activity occurred under natural drought conditions, even with severe stress, however, if desiccation was unnaturally fast, reduction in activity occurred. Most of the literature reporting reduction in the Hill reaction with moderate water deficits were performed with potted plants or excised leaves which were desiccated rapidly.

Similar responses may occur with stomata. In sorghum the stomata may close fairly rapidly and completely when initially exposed to drought. However, in subsequent drought exposures the stomata may respond only partially. It seems important that response to previous environmental conditions be investigated in field photosynthesis measurements. Our results indicate that there are different genotypic acclimation responses and the research should be alerted to these differences. There is also evidence that sorghum stomata may not respond the same at different stages of growth.

We have also been interested in the contribution of photosynthesis by sorghum panicles to developing grain, and to the partitioning of all photosynthate between the vegetative and grain components. Very contrasting varietal differences have been found in these investigations. There seems to be minor control of water loss from the panicles, but this has not been quantitated, and the relation between water loss and photosynthetic activity of the panicle needs further investigation with possible genotypic differences evaluated.

Many of the environmental and genetic variables affecting photosynthesis can be defined only with adequately controlled environmental facilities. While these have been somewhat inadequate at Nebraska, the USDA-ARS is currently remodeling three existing low light intensity environmental chambers to high intensity better quality light for use in this type of research at Lincoln. Need still exists, however, for large controlled environment rooms where taller genotypes and greater numbers of plants can be grown. Availability of the North Carolina phytotrons for ARS research could possibly be utilized for some of this research. Even with good controlled environment facilities, it is believed that all responses must be ultimately tested under field conditions with good environmental monitoring.

We are making special effort to work closely with the plant breeders and geneticists who are continually introducing, recombining and selecting new genetic materials for improved yields. We are presently actively assisting with physiological selections, but to help appreciably with the progress, [redacted] we must have techniques which are simple and rapid enough to be used on large numbers of plants. There are approximately 16,000 sorghum types in the world collection. We have measured very few of them for physiological or biochemical responses. It is expected that the physiological responses are as variable as the morphological, and it is only with adequate research personnel and technical assistance that we may define and utilize the possible beneficial responses found in this germ plasm pool.

Part II Summary of Individual ARS Projects

NATIONAL PROGRAM STAFF

Information for ARS Photosynthesis Workshop

Prepared by L.H. Allen, Jr. Date October 25, 1974

1. 7602-12280-002 (Pending) Drainage Requirements and Systems for Citrus in Florida.

2. Gainesville, Florida (and Ft. Pierce, Florida).

3. Leon H. Allen, Jr.
USDA-ARS
Department of Agronomy
304 Newell Hall
University of Florida
Gainesville, FL 32611

4. Current SMY - None on current CRIS, about 0.2 planned.

5. About 0.2 SMY on Photosynthesis Research.

6. (1) salaries ____________ (2) Operations ____________

7. Mission of Research. The overall mission of this Research Unit is to conduct ARS research on Soil-Water-Atmosphere-Plant problems cooperatively with the Institute of Food and Agricultural Science, University of Florida. The first phase of this research program has focussed on citrus production in poorly drained flatwoods soils of Florida. Photosynthesis and transpiration studies have been a part of the overall mission.

8. Objectives of Research. The relevant objectives for this questionaire include determining the effect of water logging and poor soil aeration on photosynthesis (carbon dioxide exchange) and transpiration in citrus, as mediated by stomatal function and other stress physiological reactions.

9. Photosynthesis research at low level at the moment. SWAP facilities have been used by cooperators on measuring effect of UV radiation on photosynthesis of several crop plants, and on peanut photosynthesis studies.

10. Significant Research Accomplishments.

E.B. Knipling. Showed that flooding and low aeration decreased photosynthesis and transpiration of citrus seedlings drastically after 1 day.

L.H. Allen, Jr. (Work with models before assuming duties at Gainesville, Fl.) (i) Model work showed aerosols and clouds redistribute direct beam radiation more favorably for certain (low light saturation) canopies of

leaves. (ii) Low effectiveness of CO_2 enrichment under field conditions was shown experimentally and by modeling photosynthesis and turbulent diffusion processes.

11. Impact. See item 10.

12. Obstacles to achieving objectives. Need more technical and/or student help.

13. Effect of flooding on root physiology of citrus, and how these conditions affect CO_2 exchange, transpiration, survival, growth and production.

14. Research, Facilities, Personnel needs.

    i. System for controlled water table in citrus plots.

    ii. System for determining CO_2 exchange by trees.

    iii. Technical support to maintain above two systems.

15. Cooperation:

    Agricultural Research Center
    Ft. Pierce, Florida

    University of Florida
    Gainesville, Florida

16. i. Photosynthesis and Transpiration of Citrus Seedlings under Flooded Conditions, H.T. Phung and E.B. Knipling, submitted to Jour. Amer. Soc. Hort. Sci.

    ii. Photosynthesis in Plant Canopies: Effect of Light Response Curves and Radiation Source Geometry. Photosynthetica 8:29-40. 1974.

    iii. Carbon Dioxide Uptake by Wide-Row Grain Sorghum Computed by the Profile Bowen Ratio. Agron. J. 66:35-41.

    iv. About 10 other photosynthesis, CO_2 exchange, or photosynthetic active radiation papers in process.

17. Other Considerations. Plans are being made to reactivate and expand CO_2 exchange research in the SWAP project.

18. Recommendations. Recommend that this scientist remain on the list of ARS scientists involved in photosynthesis research, even though present level of activity is not high, because of the importance of photosynthesis research in the overall SWAP mission.

NATIONAL PROGRAM STAFF

Format for Providing Information for
ARS Photosynthesis Workshop

Prepared by Donald N. Baker Date Nov. 3, 1974

(No more than 2 pages)

1. Number and Title of Work Reporting Unit (WRU) 7502-12330-001 "Optimization of Soil-Plant Meterrological Factors for Plant Growth with Simulation Techniques".

2. Location(s)
Mississippi State, Miss., and Clemson, S. C.

3. Scientist's Name, Address, and Telephone Number
Donald N. Baker, P. O. Box 5367, Mississippi State, Miss. 39762 - 601-323-2230

4. Current SMYs Working on Photosynthesis at Your location
1

5. Percent of Your time Spent on Phytosynthesis Research

6. Net Budget--(1) Salaries $43,550 (2) $2350.00

7. Mission of Research. The simulation of plant growth and yield.

8. Objectives of Research. To provide quantitative information on the effect of environment on photosynthesis and respiration in crops.

9. Status of Present Research. Simulation effort continues. Experimental research terminated for lack of funds.

10. Significant Research Accomplishments (Be specific and brief).

(a) Have established that crop photosynthesis is proportional to canopy light interception regardless of sun angle, plant size, row spacing or stage of development (until late maturity).

(b) Have characterized the effects of short term moisture stress, temperature and CO_2 supply on net photosynthesis in corn and cotton.

(c) Have performed canopy CO_2 assimilation measurements which have made possible the developmant of a general carbohydrate budget for a dynamic model simulating cotton growth and yield.

11. Impact of Research on Science and General Public.
    (a) Canopy light interception-photosynthesis studies have stimulated numerous similar studies in other crops by other researchers.

    (b) Simulation models of cotton growth and yield are being used as a pattern at numerous locations for development of similar models for other crops.

    (c) Models are providing first application of quantitative information on photosynthesis rates and responses to other disciplines in the plant sciences.

    (d) Models are serving as a basis for the development of economic thresholds for pest management.

12. Obstacles to Achieving Objectives. Lack of sufficient support personnel and funds.

13. Future Lines of Research for Emphasis. As funding permits we will produce data on potential growth rates of plant organs, including roots, and in the case of legumes, including nodules, under luxury supplies of photosynthate. This information is desperately needed for further development of models simulating growth and yield.

14. Research, Facilities, and Personnel Needs.
    (a) Rhizotron type facility with capability of controlling and measuring photosynthesis: to be used for studies of partitioning of photosynthate to roots and other organs.

    (b) Personnel needs: two technicians; three graduate students; and one post-doctoral fellow.

15. Extent of Cooperation - Names of Persons and Institutions.

    (a) Department of Entomology, Mississippi State University, Drs. Aubrey Harris, Larry Brown and Gordon Andrews.

    (b) Department of Agronomy, Mississippi State University, Dr. Frank Whisler.

    (c) Department of Agricultural Engineering, Clemson University, G. B. Alexander and Dr. Jerry Lambert.

    (d) USDA-ARS, Florence, South Carolina, Drs. Jim Fouss and Claude Phene.

    (e) USDA-ARS, Lubbock, Texas, Dr. Don Wanjura.

    (f) Department of Entomology, University of California at Davis, Dr. Andy Gutierrez.

16. Titles and Places of Publications in the Past Two Years.

(a) Cotton: a computer simulation of cotton growth. Ariz. Agr. Exp. Sta. Tech. Bul. 206, 124 pp. with N. M. Stapleton, Dr. R. Buxton, F. L. Watson, and D. J. Notling.

(b) SIMCOT II: a simulation of cotton growth and yield. User's Manual. 75 pp. In press. USDA-ARS Series, with J. M. McKinion, J. D. Hesketh and J. W. JOnes.

(c) Carbon dioxide and the photosynthesis of field crops: a tracer examination of turbulent transfer theory. Agron. J. 65: 574-578, with L. A. Harper, J. E. Box, Jr., and J. D. Hesketh.

(e) Aspects of predicting gross photosynthesis (net photosynthesis plus light and dark respiration) for an energy-metabolic balance in the plant. In Gates, D., (Ed.), Ecological Studies: Analysis and Synthesis. Vol. 6. Biophysical Ecology. Springer-Verlag, Berlin, with R. S. Alberte and J. D. Hesketh.

(f) An analysis of the relation between photosynthetic efficiency and yield in cotton. Proc. 1973 Beltwide Cotton Prod. Res. Confs. pp. 110-114, with R. R. Bruce and J. M. McKinion.

(g) An analysis of the exponential growth equation. Crop Sci. 14: 549-551, with J. M. McKinion, and J. D. Hesketh.

(h) An analysis of the impact of temperature and rainfall changes on growth and yield of Delta Cottons. In Vol. IV. Impact of Climatic Change in the Bioshpere. (Eds. R. Jensen and J. Bartholic). In press., with J. R. Lambert.

(i) Cotton - Chapter 10 of Crop Physiology: Some Case Histories. pp. 297-235. Ed. L. T. Evans. Cambridge University Press, with J. A. MacArthur and J. D. Hesketh.

(j) Fertilize the air over a field. Crop and Soils. pp. 8-9. Nov. 1973, with L. A. Harper and J. E. Box, Jr.

(k) Simulation of growth and yield in cotton: II. Environmental control of morphogenesis. Crop Sci. 12: 436-439, with J. D. Hesketh and W. G. Duncan.

(l) Systems analysis and the evaluation of morphogenetic characters in cotton. In The Application of Systems Methods to Crop Production Symp. Proc. June 7-8, 1973, Mississippi State University. In press, with J. N. Jenkins, and W. L. Parrott.

(m) Problems in building computer models for photosynthesis and respiration. IN Proc. Symp. " Environmental and Biological Control of Photosynthesis," Hasselt, Belgium. Aug. 26-30, 1974. In press, with J. D. Hesketh, J. M. McKinion, J. W. Jones, A. C. Thompson, and R. F. Colwick.

(n) Crop architecture in relatiohn to yield. Chapter 3 of Crop Physiology. Ed. U. S. Gupta. McGraw-Hill. In press, with R. E. C. Weaver and J. D. Hesketh.

(O) Determining an average cotton plant from mapped plants. In 1974 Proc. Beltwide Cotton Prod. Res. Confs. pp. 65-66, with J. M. McKinion, R. E. McLaughlin, and G. A. Matthews.

17. Other Considerations. With the advent of the dynamic simulation of plant growth and yield a way has been cleared to evaluate the potential social and economic impact of possible changes in the photosynthetic efficiency of crop plants. This development also provides a conduit for the application of quantitative information on photosynthesis by researchers in other disciplines.

18. Recommendations: Immediate payoffs in terms of benefits to other scientific disciplines and to the public at large through increased support of photosynthesis research in interdisciplinary teams where the overall objective in plant growth modeling may be expected. Support should be increased for the study of photosynthesis by members of teams engaged in the development of models of crop plant growth. New teams should be formed where needed.

ARS PHOTOSYNTHESIS WORKSHOP
Information Summary

Prepared by: Jesse H. Bennett   Date: October 31, 1974

Title: Reducing the effects of air pollutants on horticultural crops

WRU: 1103-14789   Location: ARS Plant Industry Station, Beltsville, Md.

Scientist: Jesse H. Bennett, Air Pollution Laboratory, AEQI
Bldg. 050, Rm. 24, BARC-W, Beltsville, Md. (telephone 344-2135)

Current SMY on Photosynthesis Research 1/2 SMY   Percent of Time: 50%
Net Budget: (1) Salary: $15,000   (2) Operations: $10,000

Mission of Research: The mission of the Air Pollution Laboratory is to determine the effects of air pollutants on plants and to develop technology for minimizing and preventing damage by use of genetic, mechanical, chemical and other methods. In achieving the objectives of this mission, a balance is maintained between basic and mission-oriented research. Emphasis is on (1) determing mechanisms of action of air pollutants, (2) evaluating effects of air pollutants on yield and quality of horticultural and field crops, and (3) identifying and developing plants with tolerance to air pollutants.

Objectives: (1) To assess the effects of phytotoxic air pollutants on productivity, quality and chemical composition of major agricultural crops and (2) to develop an understanding of the controlling factors which regulate plant sensitivity and tolerance.

Status of Present Research: Research has shown that net photosynthesis rates for certain crop canopies can be reversibly inhibited by subnecrotic exposures to a number of important air pollutants. Current research seeks to characterize and define the extent of occurrence and the mechanisms of action. Also since open-top chambers are being used to assess the impact of air pollution on crop productivity, research designed to better understand the effects of chamber vs. ambient environments on the results are being undertaken.

Significant Research Accomplishments: Past research has studied the effects of six major phytotoxic atmospheric pollutants on the apparent photosynthesis rates of alfalfa, oats and barley canopies. Net canopy CO_2 uptake rates were inhibited by the pollutants according to the following order when compared on the basis of equivalent exposure dosages applied: $HF > Cl_2 \simeq O_3 > SO_2 > NO_2 > NO$. These studies contribute new knowledge about the relative effects of low pollutant concentrations on plants. Also investigations into gas and energy exchange parameters for open-top chambers seek to evaluate chamber factors which perturb crop growth when compared with growth under ambient conditions.

Impact of Research on Science and General Public: This research is part of a broader program which seeks to evaluate the impact of phytotoxic air pollution on agricultural crops, to develop methods of diagnosing injury, and the technology to protect our plant resources.

Obstacles to Achieving Objectives: Many interrelated factors and feedback processes (both biological and environmental) combine to determine the susceptibility and response of plants to air pollutants. These include those

which affect pollutant transfer to sensitive cells as well as the physiological and morphological states of the tissues. Plants are products of the micro-environmental regimes under which they grow and they are subject to change as they develop and age. Evaluation of the impact of air pollution on plant productivity is highly complicated by the simultaneous influences of a wide variety of biotic and abiotic factors in the environment that increase or decrease the relative sensitivity of plants to air pollutants.

Future Lines of Research for Emphasis: Future research will emphasize: (1) Relationships between exposure dosage and dosage absorbed by sensitive tissues, (2) Primary mechanisms of action, and (3) Development of predictive models to aid the extension of experimental data to field crops which can be tested in the field.

Research, Facilities, and Personnel Needs: Investigations using leaf and canopy chambers, along with special diagnostic techniques, will be used (1) to further characterize pollutant absorption properties of plant tissues and (2) to study mechanisms of action based on *in vivo* physiological responses. Personnel requirements include the principal investigator and one technician during fall, winter and spring terms and the cooperative efforts of two additional principal investigators plus 3 technicians during the summer quarter.

Cooperators: Dr. Howard E. Heggestad, ARS, N.E. Region, USDA
Dr. Robert K. Howell, ARS, N.E. Region, USDA

Publications (past 2-years):

Bennett, J. H. and A. C. Hill. Absorption of air pollutants by a standardized plant canopy. J. Air Poll. Contr. Assoc. 23:203-206 (1973).

Bennett, J. H., A. C. Hill and D. M. Gates. A model for gaseous pollutant sorption by leaves. J. Air Poll. Contr. Assoc. 23:957-962 (1973).

Bennett, J. H. and A. C. Hill. Inhibition of apparent photosynthesis by air pollutants. J. Environ. Qual. 2:526-530 (1973).

White, K. L., A. C. Hill and J. H. Bennett. Synergistic inhibition of apparent photosynthetic rate of alfalfa by combinations of sulfur dioxide and nitrogen dioxide. Environ. Sci. Technol. 8:574-576 (1974).

Bennett, J. H. and A. C. Hill. Acute inhibition of apparent photosynthesis by phytotoxic air pollutants. *In* Dugger, W. M. (ed.). "Air Pollution and Plant Growth" Amer. Chem. Soc. Symposium Series (In press).

Bennett, J. H. and A. C. Hill. Interaction of air pollutants with canopies of vegetation. *In* Mudd, J. B. (ed.). "Effects of Air Pollution on Plants" Academic Press, New York (In press).

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ARS Photosynthesis Workshop

Prepared by: R. J. Bula   Date: 12-2-74

1. WRU No. 401-3302-10820

   Influence of environment on floral development in forage-crop species (environmental physiology of forage species).

2. Lafayette, Indiana

3. R. J. Bula
   Agronomy Department
   Lilly Hall of Life Sciences
   Purdue University
   West Lafayette, Indiana 47906

   Phone: 317-749-2891

   Address after December 8:
   Agricultural Research Service
   Illinois-Indiana-Ohio Area
   2336 Northwestern Avenue
   West Lafayette, Indiana 47906

   Phone: 317-633-7679 (FTS)

4. Three ARS scientists located at Lafayette are conducting research related to photosynthesis. However, none is spending full-time on this area of research. Collectively, the time amounts to about 0.3 SMY.

5. Approximately 0.1 of my time involves research related to photosynthesis.

6. Net budget at Lafayette, Indiana location:

   (1) Salaries - $10,000

   (2) Operations - $ 2,000

7. Mission of research:
   Increase the productivity of forage crops.

8. Objectives of research:

   Define the role of environment in regulating growth and development of perennial forage species. The more specific objectives relate to how the environmental variables affect the rates of various physiological processes involved in the assimilation and utilization of photosynthate in the growth, respiration, and storage processes of the leaf, stem, reproductive, and storage tissues.

9. Status of present research:

A data base, concerning plant responses to various environmental conditions (both in the field and controlled environmental chambers) has been assembled. This data base is being used to develop an alfalfa growth model (SIMED). One of the components of this growth model involves the photosynthetic processes.

10. Significant research accomplishments:

1. An alfalfa growth model has been developed that can be used for simulation studies.

2. Simulations have been conducted based on the growth model to evaluate the sensitivity of alfalfa yields to changes in radiation and temperature levels and changes in rates of the various plant processes.

11. Impact of research on science and general public:

Development of the alfalfa growth model required a comprehensive evaluation, integration, and amalgamation of how the various physiological processes interact with environmental conditions. Thus, we were able to identify areas that need additional research.

The model provides an effective means of communicating to scientists and students how crop physiology can be used to improve production and quality of forage crops.

The model can be used as an element model in a real-time simulation of an alfalfa cropping system thereby providing information for making management decisions.

12. Obstacles to achieving objectives:

The main obstacles are personnel and funds. The other aspect is that to effectively apply modeling and simulation to biological or agricultural systems requires dedicated cooperation among several divergent disciplines. ARS does not have an adequate number of such scientists. An alternative would be to provide extramural funds for support of cooperative research. This should be an active cooperative program between non-ARS and ARS scientists.

13. Future lines of research for emphasis:

Refinement of the photosynthesis component of the alfalfa model in terms of how photosynthetic rates are affected by internal and external factors.

Use of simulation results to guide management and breeding research programs.

14. Research, facilities, and personnel needs:

Additional funds and personnel are needed if the program at this location is to function more effectively. Present program is only a small segment of the professional effort.

15. Extent of cooperation:

Excellent cooperation exists between the ARS program and staff of Purdue University.

Purdue staff are:

D. A. Holt, Department of Agronomy
R. A. Dilley, Department of Biological Sciences
H. R. Koller, Department of Agronomy
G. A. Miles, Department of Agricultural Engineering
R. M. Peart, Department of Agricultural Engineering

16. Titles and places of publications in the past two years:

1. Simulation of alfalfa growth, Am. Soc. Agric. Eng. Paper No. 73-4547, St. Joseph, MI., also presented at Am. Soc. Agron. Annual Meetings, 1973 and 1974. Agronomy Abstracts.

2. Complementary aspects of phytotron and field facilities in environmental physiology research. Agric. Sci. Rev.

3. Climatic factors in forage production. In Forages, the Science of Grassland Agriculture, Heath, Metcalfe, and Barnes, ed., Iowa State Univ. Press.

NATIONAL PROGRAM STAFF

Format for Providing Information for
ARS Photosynthesis Workshop

Prepared by: Gerald E. Carlson Date: November 1, 1974

1 Number and Title of Work Reporting Unit (WRU): 1109-10811, Improved Forage Varieties and Production Practices for Humid and Irrigated Conditions

2 Location: Light and Plant Growth Laboratory, Plant Physiology Institute, Beltsville Agricultural Research Center, Beltsville, Maryland 20705

3 Scientist's Name, Address, and Telephone Number: Gerald E. Carlson, Laboratory Chief, Light and Plant Growth Laboratory, ARS, USDA, Building 046-A, BARC-W, Beltsville, Maryland, 20705; (301) 344-3295

4 Current SMYs Working on Photosynthesis at Your Location: Carlson, 0.5; and Chatterton, 1.0

The Following Items Pertain Specifically to G. E. Carlson

5 Percent of Your Time Spent on Photosynthesis Research: 50 percent

6 Net Budget--(1) Salaries $30,000 (2) Operation $2000

7 Mission of Research: To identify and understand key processes of energy transformation and CO_2 fixation such that techniques of selection can be used to develop plant genotypes which more efficiently utilize the natural resources in production of food and feed.

8 Objective of Research: (1) Develop techniques for measuring carbon dioxide exchange of leaves, whole plants, and communities; and (2) Identify environmental factors limiting utilization of photosynthate, e.g. light, temperature, nutrients, etc.

9 Status of Present Research: Semi-dormant--owing to program management of the laboratory, completion of a phase of the research, and awaiting the outcome of photosynthesis workshop.

10 Significant Research Accomplishments: (1) Developed improved techniques for determining net carbon dioxide exchange of leaves of grass and legumes, specifically orchardgrass and alfalfa; (2) Identified genotypic differences for net carbon dioxide exchange of alfalfa and orchardgrass; (3) Established relationship between net carbon dioxide exchange and specific leaf weight of forages; and (4) Evaluated the relationship of net carbon dioxide exchange, specific leaf weight and yield in the field of selected genotypes.

11 Impact of Research on Science and General Public: Research accomplishments to date indicate that the photosynthetic process itself is markedly affected by genotype, environment, and processes such as translocation and tillering. Continued measurement of net carbon dioxide exchange should be considered as one important parameter in the total study of energy conversion including transport, deposition, and regulation of energy conversion.

12 Obstacles to Achieving Objectives: Lack of personnel to develop a program that will deal intensively and indepth with key physiological and biochemical problems and also be able to interact with researchers in more extensive areas such as production and breeding.

13 Future Lines of Research for Emphasis: Development of techique for measuring carbon dioxide exchange in tissue and cell culture research, and define specific effects of light quanity and quality on fixation, transportation, and utilization of photosynthates.

14 Research, Facilities, and Personnel Needs: Facilities are generally adequate, but additional personnel are needed to create the necessary depth and scope to work as an effective team.

15 Extent of Cooperation--Names of Persons and Institutions: Dr. N. J. Chatterton within the Light and Plant Growth Laboratory. Past cooperation included: Dale Wolfe, Virginia Polytechnic Institute, Blacksburg, Virginia; D. K. Barnes, Alfalfa Investigations, Beltsville, Maryland; and S. H. West, Humid Pasture and Range Investigations, University of Florida, Gainesville, Florida.

16 Titles and Places of Publications in the Past Two Years:

Chatterton, N. J., G. E. Carlson, W. E. Hungerford, and D. R. Lee. The effect of tillering and cool nights on photosynthesis and chloroplast starch in Pangola. Crop Sci. 12:206-208. 1972.

Carlson, G. E., N. J. Chatterton, and R. H. Hart. Physiological and morphological basis for the relationship of yield and survival in alfalfa. Proc. XII Intl. Grassl. Cong. Moscow, USSR. 1974.

Chatterton, N. J., G. E. Carlson, R. H. Hart, and W. E. Hungerford. Tillering, nonstructural carbohydrates and survivial relationships in alfalfa. In Press. Crop Science.

17 Other Considerations: None

18 Recommendations: At this time, a major one is being implemented, namely an ARS workshop on photosynthesis.

November 4, 1974

INFORMATION FOR ARS PHOTOSYNTHESIS WORKSHOP prepared by

Chong W. Chang

1. 5510-10590

2. Western Cotton Research Laboratory. 4135 E. Broadway, Phoenix, Arizona 85040

3. Chong W. Chang, Western Cotton Research Laboratory, Phoenix, Ariz. 85040

4. One

5. 100 percent

6. Budget: Salary: 30,000 Operations: 10,000

7. Determine chemical and enzymatic limitations on photosynthetic efficiency in cotton plants.

8. Objectives of this research are to characterize the carbon fixation process in cotton from CO_2 to starch and to examine the remobilization of starch for translocation at night. The enzymatic steps, particularly the activities of amylose and amylopectin, will be characterized to find the rate limiting steps which cause cotton to be less efficient than many other field crops.

9. The present research is concentrated on investigation into the factual status of starch and its component distributions among the leaves of various ages during cotton plant development. This work would tell us possible relationships among starch accumulation, starch degradation, and the ratios of starch components during leaf growth. The components of starch, amylopectin and amylose, have different affinities for enzymes responsible for starch formation and degradation. The effort to control the enzymes responsible for branching and debranching starch molecules is one goal, albeit difficult.

10. To improve photosynthetic efficiency, introduction of more CO_2 into the carbon reduction cycle was conducted. A successful result was

obtained when young cotton leaves were subjected to the concentration of 850 ppm CO_2 for 15 days. This was evidenced by the fact that carbonic anhydrase activity showed a gradual increase. However, 1000 ppm CO_2 induced senescence, because an extremely wide concentration range of low bicarbonate directly inhibited the rate of photophosphorylation and that of the Hill reaction. The catalytic hydration of CO_2 by carbonic anhydrase was also involved.

11. As a major field crop producing both food and fiber, the productive efficiency of cotton is of keen interest in all temperate climates. This research is aimed at uncovering ways of improving productive efficiency by finding the limitation on photosynthesis which may imply methods for improving this efficiency.

12. Lack of manpower is one of the obstacles to achieving objectives.

13. More emphasis will be focused on controlling starch translocation by environmental and/or enzymatic approach, after finding more information from the present research.

14. The present facilities are good enough for the present research. However, as the work advances, more will be needed. A full-time assistant is necessary at this moment.

15. Dr. J. R. Mauney and Dr. G. Guinn.

16. (a) Chong W. Chang: Carbonic anhydrase in carbon dioxide-induced senescence of cotton leaves. Proceedings, Beltwide Cotton Production Research Conferences. Jan. 7-9, 1974 (Dallas, Texas).

    (b) Chong W. Chang: Carbonic anhydrase of cotton plants. (in press, Phytochemistry, 1974).

    (c) Chong W. Chang: Manometric method for determining bicarbonate content in plant leaves (in press, Analytical Biochemistry, 1974).

    (d) Chong W. Chang: Carbon dioxide and senescence in cotton plants. (Accepted in Plant Physiology).

17. None

18. None

NATIONAL PROGRAM STAFF

Format for Providing Information for
ARS Photosynthesis Workshop

Prepared by: N. Jerry Chatterton   Date: November 1, 1974

1 Number and Title of Work Reporting Unit (WRU): 1109-10811, Improved Forage Varieties and Production Practices for Humid and Irrigated Conditions

2 Location: Light and Plant Growth Laboratory, Plant Physiology Institute, Beltsville Agricultural Research Center, Beltsville, Maryland 20705

3 Scientist's Name, Address, and Telephone Number: N. Jerry Chatterton, Plant Physiologist, Light and Plant Growth Laboratory, ARS, USDA, Building 046-A, BARC-W, Beltsville, Maryland 20705; (301) 344-3607

4 Current SMYs Working on Photosynthesis at Your Location: Chatterton, 1.0; and Carlson, 0.5

The Following Items Pertain Specifically to N. J. Chatterton

5 Percent of Your Time Spent on Photosynthesis Research: 90 percent

6 Net Budget--(1) Salaries $34,000 (2) Operation $3350

7 Mission of Research: To identify and understand key processes of energy transformation and CO_2 fixation such that techniques of selection can be used to develop plant genotypes which more efficiently utilize the natural resources in production of food and feed.

8 Objectives of Research: To establish interrelationships among photosynthetic rate, energy charge, and translocation, thereby identifying yield limiting processes in forage and other crops.

9 Status of Present Research: It has been demonstrated that some plants do not express their full photosynthetic potential most of the time. The problem, therefore, lies in manipulating the plant such that more of its photosynthetic potential is utilized.

10 Significant Research Accomplishments: The dynamics of the plant system have been reemphasized. Adenylate energy charge has been implicated in the assimilate accumulation associated reduction of photosynthesis. The process of tillering has been shown to influence not only carbohydrate reserves, but winter survival and yield of forages.

11 Impact of Research on Science and General Public: A contribution has been made to the understanding that photosynthesis is a dynamic process that varies diurnally as well as with morphological development of the plant. Therefore, many plants have a photosynthetic potential in excess of that expressed most of the time. An appropriate question now is "How can we develop plants that express their full potential for a greater portion of their time?" in addition to the more commonly asked one, "How can we increase the photosynthetic potential of plants?"

12 Obstacles to Achieving Objectives: The fantastic complexity of nature.

13 Future Lines of Research for Emphasis: A concentrated effort will be made to identify physiological factors or characteristics that limit crop production. Specifically the role of adenosine phosphates in control and regulation of assimilation related processes will be investigated.

14 Research, Facilities, and Personnel Needs: Considerable updating of the photosynthetic laboratory and laboratory equipment at our location is needed.

15 Extent of Cooperation--Names of Persons and Institutions: G. E. Carlson, Light and Plant Growth Laboratory, Beltsville, Maryland; T. M. Ching, Oregon State University, Corvallis, Oregon; J. B. Powell, USDA, ARS, Plant Genetics and Germplasm Institute, Beltsville, Maryland; and W. W. Hanna, USDA, ARS, Coastal Plain Experiment Station, Tifton, Georgia.

16 Titles and Places of Publications in the Past Two Years:

Chatterton, N. J., G. E. Carlson, W. E. Hungerford, and D. R. Lee The effect of tillering and cool nights on photosynthesis and chloroplast starch in Pangola. Crop Sci. 12:206-208. 1972.

Chatterton, N. J., D. R. Lee, and W. E. Hungerford. Diurnal change in specific leaf weight of *Medicago sativa* L. and *Zea mays* L. Crop Sci. 12:576-578. 1972.

Chatterton, N. J. Product inhibition of photosynthesis in alfalfa leaves as related to specific leaf weight. Crop Sci. 13:284-285. 1972.

Chatterton, N. J., and D. R. Lee. A leaf chamber to measure photosynthesis and transpiration of intact grass leaf sections. Crop Sci. 13:576. 1973.

Carlson, G. E., N. J. Chatterton, and R. H. Hart. Physiological and morphological basis for yield and survival of alfalfa. Proc. XII Intl. Grassl. Cong., Moscow, USSR. 1974

Chatterton, N. J., G. E. Carlson, R. H. Hart, and W. E. Hungerford. Tillering, nonstructural carbohydrates and survival in alfalfa. Crop Sci 14:(In Press) 1974.

Chatterton, N. J. and Jerrel B. Powell. Stomatal guard cell integrity and resistance to rumen fluid digestion. Agron. J. 66:(In Press) 1974.

17 Other Considerations: Administration must aleviate the excessively long time period (60-90 days) required for ARS approval of manuscripts (specifically time in the Technical Editors office).

18 Recommendations: That ARS develop a coordinated program of photosynthetic research, that teams of complimenting scientists concentrate on specific approaches to increasing crop production through a better understanding of the photosynthetic process.

ARS Photosynthesis Workshop

Prepared by E. H. Coe, Jr. 13 December 1974

1. Work Reporting Unit 3402-10470-002, Corn improvement through research in genetics and cytogenetics.

2. Location: Columbia, Missouri.

3. Scientist: E. H. Coe, Jr., Curtis Hall, University of Missouri, Columbia, MO 65201. Phone (314) 882-2768 commercial.

4. Directly on Photosynthesis: Estimate 0.2 SMY.

5. Percent of Time Spent on Photosynthesis Research Directly: 20%.

6. Net Budget (prorated): (1) Salaries $8,000 (2) Operations $1,700.

7,8. Mission and Objectives of Research: Broaden basic genetic and cytogenetic knowledge in corn to increase our understanding of mechanisms of gene action and chromosomal behavior and establish more reliable bases and more efficient means for crop improvement.

9. Status of Present Research: Research program in the specific genetics of corn and in genetic and cytogenetic methodologies with crop plants. Initiating studies on inheritance systems of components of cell organelles.

10. Significant Research Accomplishments: Identification of origin of anomalies in sexual fertilization, including selection methods for haploids; characterization of mechanism of paramutation, an unorthodox form of inheritance; Compilation of research aids in the genetics of corn; genetic characterization of factors controlling anthocyanin synthesis, including their sequence of action.

11. Impact of Research on Science and General Public: Materials and procedures provided for genetic manipulation; models and knowledge for understanding complex systems.

12. Obstacles to Achieving Objectives: Underdeveloped professional-level communication, sharing of skills and collaborations; limitations in technical help in both numbers and skills; severely restricted discretionary funds; some inadequacies in facilities and equipment for plant culture.

13. Future Lines of Research for Emphasis: Organelle inheritance systems; genetic analysis devices and methods; regulation and control in genetic systems.

14. Research, Facilities, and Personnel Needs: Technical help, discretionary funds and special-request funds consonant with present program needs and with developing progress in the research; for professional level needs, funds for travel, exchange, or postdoctoral arrangements.

15. Extent of Cooperation: W. F. Sheridan, University of Missouri, C. D. Miles, University of Missouri; supply materials frequently to others on request, including some workers in photosynthesis area; collaborations with others not directly pertinent to photosynthesis.

16. Publications: _C_ locus control of anthocyanin synthesis in maize (Abst. in Genetics, with S. M. Hsu-Chen); Corn (Maize), Chapter in _Handbook of Genetics_ edited by R. C. King, in press (with M. G. Neuffer); The Genetics of Maize, Chapter in _Corn and Corn Improvement_ edited by G. F. Sprague; Amer. Soc. Agron.; accepted, in revision (with M. G. Neuffer).

17. Other Considerations: Genetics of plant geometry is in its infancy, and will need attention.

18. Recommendations: Consider formation of a research committee, to meet annually and to interact continuously; convey the vital importance of this area of knowledge and its utility, and the remediable obstacles, to the appropriate places.

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Information for ARS
Photosynthesis Workshop

Prepared by Clee Cooper Date 10-15-74

1. Work Unit Number and Title:
5708-15550-002 Irrigated Pasture Establishment and Management.

2. Location:
Bozeman, Montana 59715

3. Personel:
Clee S. Cooper, Plant & Soil Science Dept., Montana State University, Bozeman, Montana 59715, Telephone 406-994-4601.

4. Current SMYs on Photosynthesis:
.2

5. Percent of time on photosynthesis:
.2 SYM

6. Net Budget:
(a) salaries $ 26,200
(b) operations $ 5,400

7. Mission of research:
Develop superior grass-legume mixtures for irrigated pastures, dependable procedures for establishing them and management procedures that will insure maximum productivity.

8. Objectives of Research:
(a) to increase production effeciency by developing superior mixtures and management practices for irrigated pastures,
(b) to delineate basic physiological and morphological factors which have implications for better establishment and increased biological efficiency and yield of forages.

9. Status of Present Research:
Major emphasis is currently being spent on the effect of canopy structure on light penetration; evaluation of the photosynthetic rate of cotyledons to seedling vigor; studies of shade effects on photosynthesis; and continued compounding and testing of pasture mixtures.

10. Recent research accomplishments relative to photosynthesis:
Showed that some leaves have more stomata, more palisade and mesophyll cells, and less chlorophyll per unit of area but more chlorphyll per unit of weight than shade leaves.
Defined interrelationships of stored and synthesized energy to growth of the corn seedling.
Reported the effects of leaf color, chlorophyll content and temperature on photosynthesis of isogenic barley lines.

Showed that the sainfoin cotyledon is a major assimilatory organ and published the first paper showing the relative cotyledon contribution to total seedling photosynthesis.
Showed that trifoliate first leaves of sainfoin are larger and photosynthesize morethan unifoliate first leaves with a resultant increase in seedling vigor.
Showed that shading of mature leaves can affect the specific leaf weight of new leaves formed in the sun.

11. Impact of Research on Science and General Public:
Work published has contributed to an understanding of factors affecting seedling vigor and photosynthesis. Several of the criteria for evaluating seedling vigor are being incorporated into plant breeding programs in Montana.

12. Obstacles to Achieving Objectives:
Funding is the main limiting factor at the location. The program is presently limited to one full time scientist and part time student help. This means that the major effort is limited to the summer when help is available. Funds have not been available to buy such things as a high intensity light source, which is a necessary prerequisite for work in photosynthesis.

13. Future Lines of Research for Emphasis:
Major emphasis for the next 5 years will be in studies of canopy structure effects on light penetration. This work should be expanded to include effects of canopy strucutre on photosynthetic rate, but the expansion requires equipment for which funds are not available.

14. Research, Facilities, and Personnel Needs:
(1) one high intensity Xenon light
(2) two high intensity growth chambers
(3) funds for building chambers to enclose artifically constructed canopies for photosynthetic measurements
(4) 1 full time technician (GS -5 or above)
(5) funds for labor (3 part time students)

15. Extent of Cooperation:
Dr. J. R. Brown, Crop Physiologist
Montana State University
Dr. Raymond Ditterline, Plant Breeder
Montana State University
Plant & Soil Science Dept.
Bozeman, Montana 59715

16. Titles and Places of Publications in the Past Two Years:
1 Carleton, A. E. and C. S. Cooper. 1972. Seed size effects upon seedling vigor of three legumes. Crop Sci. 12: 183-186.

2 White, Larry M., Clee S. Cooper and Jarvis H. Brown. 1972. Nitrogen fertilization and clipping effects on green needlegrass (Stipa viridula trin.) I. Development Growth, Yield and Quality. Agron. J. 64: 328-331.

3 Krall, J. L., C. S. Cooper, C. W. Crowell and A. R. Jarvi. 1972. Evaluations of sainfoin for irrigated pasture. Mont. Agr. Expt. Sta. Bull. 658.

4 Straley, C. S., C. S. Cooper, and A. E. Carleton. 1972. Environmental influence on specific leaf weight and its heritability in sainfoin. Crop Science. 12: 474-475.

5 Cooper, Clee S. 1972. Establishment, hay yield and persistence of two sainfoin (Onobrychis viciaefolia Scop.) growth types seeded alone and with low-growing grasses and legumes. Agron. J. 64: 379-381.

6 Ferguson, A. H., C. S. Cooper, J. Brown and R. F. Eslick. 1972. Effect of leaf color, chlorophyll concentration and temperature on photosynthetic rates of isogenic barley lines. Agron. J. 64: 671-673.

7 Cooper, C. S. 1972. Growth analysis of two sainfoin (Onobrychis viciaefolia Scop.) Cultivars. Agron. J. 64: 611-613.

8 White, Larry M., Brown, Jarvis H. and Clee S. Cooper. 1972. Nitrogen Fertilization and clipping effects on green needlegrass (Stipa viridula trin.) III carbohydrate reserves. Agron. J. 64: 824-828.

9 Straley, C. S. and C. S. Cooper. 1972. Effect of shading mature leaves of alfalfa and sainfoin plants on specific leaf weight of leaves formed in sunlight. Crop Sci. 12: 703-704.

10 Cooper, C. S. 1973. Sainfoin-birdsfoot trefoil mixtures for pasture, hay-pasture and hay-stockpile management regimes. Agron. J. 65 752-754.

11 Cooper, C. S. 1973. Forage integration. Montana Farmer Stockman Vol. 61: No. 1, p 44-45.

12 Cooper, C. S. 1974. Birdsfoot trefoil gets high marks. Montana Farmer-Stockman, Vol. 61: No. 7 p 22-23.

13 Cooper, C. S. 1974. White clover for perennial pastures. Montana Farmer Stockman. Vol. 61 No. 19 p 28.

14 Cooper, C. S. and S. C. Fransen. 1974. In Press. Contribution of cotyledons to growth of the sainfoin (Onobrychis viciaefolia Scop.) seedling. Crop Sci. Accepted for publication July 16, 1974.

15 Cooper, C. S. 1974. In Press. Significance of first leaf type to growth of the sainfoin (Onobrychis viciaefolia Scop.) seedling. Crop Sci. Accepted for publication ________________.

16 Cooper, C. S. 1974. In Press. Influence of harvest management and mid-season nitrogen fertilization on yield, botanical composition, and crude protein content of grass-legume mixtures. Mont. Agr. Exp. Sta. Bull. Accepted for publication 3-15-74.

17. Other Considerations:
None

18. Recommendations:
None

BACKGROUND MATERIAL FOR WORKSHOP ON IMPROVING PHOTOSYNTHETIC EFFICIENCY OF CROP PLANTS

Prepared by Donald W. De Jong Date Dec. 12, 1974

1. Work reporting unit (WRU)

   Number: 10770
   Title: Improved Tobacco Varieties and Tobacco Production Practices

2. Location: Oxford, N. C., Mid-Atlantic Area, Southern Region.

3. Scientist's Name: Donald W. De Jong
   Discipline: Plant Biochemistry
   Address: Tobacco Research Laboratory
   Oxford, N. C. 27565
   Telephone: 919-693-5151

4. Current SMY's: 10

5. Percentage of time on photosynthetic research: 20% of 1 SMY

6. Estimated Gross Budget of Station:

   (1) Salaries $574,800
   (2) Operations $117,700

7. Mission: Chemical and Physical Factors Affecting Leaf Quality.

8. Objectives:

   (1) Study enzymes systems suspected to be involved in leaf senescence.
   (2) Study biochemical differences between green and yellow-green types of tobacco.
   (3) Develop commercially feasible homogenized leaf curing process.

9. Present Status:

   (1) Patent obtained for homogenized leaf curing (HLC). Registered with U.S. Patent Office -- No. 3845774.
   (2) Large 2000 lb lots of HLC tobacco have been produced for cigarette making and smoke analyses, including bioassay.
   (3) Substantial progress has been made in field yellowing, once-over harvesting, grinding and drying operations for HLC.
   (4) Some knowledge has been gained with respect to the chloroplasts properties and enzyme behavior of green and yellow-green tobacco that help to explain the growth vigor and early maturation of yellow-green tobacco type.
   (5) Some of the biochemical effects of senescence inducing chemicals, eg. ethylene, on chlorophyll degradation and enzyme changes have been elucidated.

10. Significant research accomplishments:

(1) Demonstrated histochemical localization of enzymes in plant tissues, especially peroxidases and acid phosphatases.
(2) Characterized the enzyme system in Botrytis cinerea extracts responsible for improving the color and flavor of white wines treated with these extracts.
(3) Defined the effects of environmental conditions on malate dehydrogenase and peroxidase isoenzyme composition of plant cells and tissues.
(4) Determined the nature of the interaction of polyphenols, such as chlorogenic acid, with glycolate oxidase of tobacco leaves.
(5) Correlated photosynthetic efficiency with chloroplast properties of yellow-green mutant of tobacco.
(6) Developed a successful method for homogenized leaf curing of Bright type tobacco.

11. Impact on science and general public:

(1) Discovery of the specific enzyme activation effect of 2% glutaraldehyde applied to plant cells grown in suspension cultures led to a practical process for producing insolubilized active enzymes of potential utility for food processing technology.
(2) Discovery of the use of freeze dried "gray mold", Botrytis cinerea for modifying wines led to a commercially feasible process for improving flavor and preventing browning of Sauterne type white wines.
(3) Discovery of the combination of using chemical ripening agents, metabisulfite as antioxidant, and vacuum drying of Bright type tobacco led to a satisfactory method for producing homogenized cured tobacco with light color, good aroma and a promising potential for diminishing the health hazards of cigarette tobacco.

12. Obstacles to achieving objectives:

Insufficient funding to properly staff the laboratory, buy necessary equipment and hire adequate technical help.

13. Future lines of research:

(1) Since outside funds have been available for developing new tobacco curing methods, sustained research into the engineering and agronomic aspects of the process will be continued until a fully integrated system is achieved.
(2) Research will be continued to investigate more carefully the biochemical differences between green and yellow-green tobacco types.
(3) Research will be continued to determine the enzymic mechanisms involved in the chemically induced senescence and subsequent curing of tobacco.

14. Research, facilities and personnel needs:

(1) There is a need to expand research beyond that of tobacco production.
(2) There is a need for additional greenhouse space and a new pilot plant building.
(3) There is a need for 4 additional scientists.

15. Extent of cooperation:

Research on homogenized leaf curing (HLC) of tobacco has necessitated cooperation with a number of other scientists:

Dr. K. R. Keller, Asst. Dir. Res., Tobacco, N. C. State Univ. Raleigh, N. C.
Mr. C. Ray Campbell, Superintendent, N. C. Dept. of Agr. Expt. Sta., Oxford, N. C.
Mr. J. J. Lam, Jr., Agr. Engin., Tobacco Res. Lab., Oxford, N.C.
Dr. T. C. Tso, Plant Physiol., Plant Gen. & Germplasm Inst., Beltsville, Md.
Dr. R. H. Lowe, Univ. of Ky., Plant Physiologist, USDA, Lexington, Ky.
Mr. Elmon Yoder, Agr. Engin., Univ. of Ky., USDA, Lexington, Ky.
Dr. Tom Owen, Asst. Dir., Smoking and Health Program, Nat. Cancer Inst., Bethesda, Md.

16. Titles of Publications (last 2 yrs.):

(1) De Jong, D. W., and A. C. Olson. Electrophoretic migration and redox behavior of malate dehydrogenases from cell suspension cultures of tobacco. Biochim. Biophys. Acta. 276: 53-62. 1972.

(2) De Jong, D. W. Detergent extraction of enzymes from tobacco leaves varying in maturity. Plant Physiol. 50: 733-737. 1972.

(3) De Jong, D. W. Modification of tobacco leaf glycolate oxidase activity by chlorogenic acid and other polyphenols. Physiol. Plantarum 29: 150-156. 1973.

(4) De Jong, D. W. Effect of temperature and daylength on peroxidase and malate (NAD) dehydrogenase isozyme composition in tobacco leaf extracts. Amer. J. Bot. 60: 846-852. 1973.

(5) De Jong, D. W. The influence of growth conditions and leaf maturity in relation to the chlorogenic acid stimulation of glycolate oxidase from tobacco leaves. Can. J. Bot. 52: 209-215. 1974.

(6) De Jong, D. W. and W. G. Woodlief. Chloroplast properties as causative factors for growth performance of pale-yellow tobacco hybrid. Tob. Sci. 29: 105-107. 1974.

(7) Tso, T. C., R. Lowe, and D. W. De Jong. Homogenized leaf curing. I. Theoretical basis and some preliminary results. Beiträge zur Tabak forschung. 1974. (Accepted for publication 5/74).

(8) De Jong, D. W., J. Lam, R. Lowe, E. Yoder, and T. C. Tso. Homogenized leaf curing. II. Bright tobacco. Beiträge zur Tabak forschung. 1974. (Accepted for publication 9/74).

17. Other considerations:

Research experience has been both of a fundamental nature, particularly relating to enzyme analyses and photosynthetic studies, as well as, of a practical nature involving development of processing applications.

Laboratory and field space at Oxford, N. C. location is adequate.

18. Recommendations:

(1) Divert some of research efforts from tobacco production into selection of alternate crops for Southeast U.S.A. Region -- preferably those considered to be of value for preparing foodstuffs and feed supplements.
(2) Examine plant species and process methods for obtaining concentrated high quality leaf protein.
(3) Engage in more concerted attack on problems of improving photosynthetic efficiency of crop plants.

Information for ARS Photosynthesis Workshop for

NATIONAL PROGRAM STAFF

Prepared by J. M. Dunleavy Date 10/23/74

1. Number and Title of Work Reporting Unit (WRU)
3090-10611-001A The role of peroxidase isoenzymes in soybean production.

2. Location(s) Ames, Iowa

3. Scientist's Name, Address, and Telephone Number: Dr. N. V. R. Urs, Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa 50010. 515-294-4560.

4. Current SMYs Working on Photosynthesis at Your Location: One SMY working about half-time on photosynthesis related research.

5. Percent of Your Time Spent on Photosynthesis Research: Urs 50%

6. Net Budget--(1) Salaries 10,000 (2) Operations 2,500

7. Mission of Research: Host-parasite relations

8. Objectives of Research: To determine the cytological site of virus induced increase in peroxidase and to attempt to relate increased peroxidase to yield loss.

9. Status of Present Research: Two year contract research with 6 months research remaining to be done.

10. Significant Research Accomplishments: The level of peroxidase activity in isolated chloroplasts and mitochondria from greenhouse grown plants was greater in soybean mosaic inoculated plants than in noninoculated plants. Peroxidase activity in mitochondrial preparations was always greater than from those of chloroplast preparations. The effect of virus infection on the Hill reaction in isolated chloroplasts was dependent on age of the leaf. Younger leaves showed a greater difference in the Hill reaction.

11. Impact of Research on Science and General Public: Relatively little impact. Value of research lies in improved understanding of role of peroxidase in plant.

12. Obstacles to Achieving Objectives: Poor understanding of virus-plant organelle interaction.

13. Future Lines of Research for Emphasis: How does viral RNA specifically trigger the increased peroxidase activity in infected plants?

16. No publications in last two years relating to photosynthesis.

NATIONAL PROGRAM STAFF
ARS Photosynthesis Workshop

Prepared by Herbert J. Dutton   Date October 25, 1974

1. 3102-12340-001 Increased Photosynthetic Efficiency of Plants Through Yellow Chloroplast Pigments

2. Peoria, Illinois

3. Herbert J. Dutton, Northern Regional Research Center, 1815 North University, Peoria, Illinois 61604, 309 685-4011 x 256

4. 1.4 SMY

5. 40%

6. (1) FY 1975 $33,700   (2) FY 1975 $1200

7. Increase photosynthetic efficiency of plants

8. Increase light absorption and photosynthesis in green and yellow regions of sun's spectrum through carotenoid sensitized photosynthesis and associated enzymes.

9. High intensity sources and monochromatators (spectrophotofluorimeter), light and oxygen measuring devices and computer interfacing have been assembled in laboratory space equipped for radiation experiments. Algal cultures have been acquired and are being cultured heterotrophically in single cell suspensions. Preliminary spectrophotofluorescence measurements on extracted chloroplast pigments are underway.

10. Past research by the Project Leader has demonstrated carotenoid sensitization of photosynthesis, high efficiency energy transfer from carotenoid to chlorophyll molecules and chromatic adaptation of submerged acquatic plants (reprints attached).

11. Wide impact of photosynthesis research is self-evident in the following two quotes:

"We are currently getting less than one-half of one percent of energy available out there....The opportunity for increased productivity in agriculture is tremendous"--Earl Butz

"The sun offers an almost unlimited supply of energy if we can learn to use it economically"--Richard Nixon

12. (see 14 below)

13. Further investigations of the action spectrum of Photo System II, on various algal species and then on higher plants such as soybean, corn, their mutants and genetic varieties in cooperative studies with the staff of the U.S. Regional Soybean Laboratory, Urbana, Illinois, are anticipated.

Millisecond experiments involving high intensity flashes of monochromatic radiation from tunable lasers at low temperature coupled with the monitoring of Chlorophyll P700 cytochrome and other cellular intermediates by differential absorption spectrometry are contemplated.

14. Much of instrumental, computer, and biological growth facilities are available for the immediate phases of algal experiments. Work on economic crops, e.g., soybeans, will be conducted in cooperation with ARS's U.S. Regional Soybean Laboratory in Urbana, Illinois, or alternatively by greenhouse construction at NRRC. Lasers, high speed amplifiers and computer interfaces for millisecond experiments will be required as the project develops. As the photochemical and kinetic aspects of photosynthesis develops a senior person of physical-chemical, electronic and computer orientation will be required to compliment training of present personnel and bring staffing up to the projected level. Further orderly expansion of research facilities and personnel should depend on the success of research presently projected.

15. Close cooperation with Drs. Ogren, Peters and Cooper of the U.S. Regional Soybean Laboratory are anticipated particularly when extensions of research to economic plants is initiated. Visits, correspondence and discussion in the early phases of developing this project has been carried on with Drs. Winslow Briggs, David Fork and C. S. French, Department of Biology, Carnegie Institute of Washington, Stanford; Dr. L. N. M. Duysens, Biophysical Laboratory of the State University, Leiden, Holland; and Professor Govinjee, Department of Botany, University of Illinois, Urbana (see sabbatical plans--17 below).

16. Because two of the three publications listed below have been widely cited as basic to advances in present knowledge of photosynthesis and because they represent the present point of research departure, they are cited despite the dates of their publication (reprints attached):

a. Carotenoid-Sensitized Photosynthesis in the Diatom _Nitzchia closterium_, Amer. J. of Bot. _28_(7): 516-526 (1941). Dutton and Manning

b. Chlorophyll Fluorescence and Energy Transfer in the Diatom _Nitzschia closterium_, J. Phys. Chem. _47_(4): 308-313 (1943). Dutton _et al_.

c. Chromatic Adaptation in Relation to Color and Depth Distribution of Freshwater Phytoplankton and Large Aquatic Plants, Ecology _25_(3): 273-282 (1944). Dutton and Juday

17. A 9-month training leave has been approved in principle and preliminary application has been made to Carnegie Institute of Washington on the Stanford Campus. However a building and renovation program of the Department makes this "sabbatical" impossible until after March 1, 1975. As an alternative, study at Leiden, Holland, has been explored. Work at either of these locations should assist in making our future work timely and significant. Their consultation on research program has been offered, accepted and incorporated in our current research.

18. Research on photosynthesis is necessarily basic and long range. Research leads for tomorrow come best from research done today. An orderly expansion of research work as progress and accomplishments justifies over a 5-year period holds the most efficient procedure for research management.

NATIONAL PROGRAM STAFF

Prepared by C. Dean Dybing Date October 30, 1974

1. Number and Title of Work Reporting Unit (WRU): 10640 Improved Flax and Production

2. Location(s): Brookings, SD

3. C. Dean Dybing
Plant Science Department
South Dakota State University, ARS, USDA
Brookings, SD 57006
Telephone: 605-688-5156

4. Current SMYs Working on Photosynthesis at Your Location: 0.35

5. Percent of Your Time Spent on Photosynthesis Research: 10% or less in FY-75

6. Net Budget--(1) Salaries $3875.00 (2) Operations $465.00

7. Mission of Research: Agricultural Production Efficiency

8. Objectives of Research: Determine physiological activities such as photosynthesis, translocation, and energy storage, of the shoot and inflorescence as related to yield. Determine the effects of growth regulators on bud development, enhancement of metabolic efficiency, yield, and senescence. Determine morphological characteristics which appear to impart high yield; measure varietal differences and variety-environment interrelationships.

9. Status of Present Research: Studies on the nutritional and hormonal regulation of flowering and fruiting in flax have been in progress since 1966. This work has concentrated on hormonal aspects since 1968, and photosynthesis has been only a peripheral part of the work. Net assimilation rates of high, medium, and low yielding flax cultivars were measured in the summer of 1974.

10. Significant Research Accomplishments: Two types of bud inhibition have been demonstrated which may have important roles in the limitation of yield. One type involves terminal buds and regulates the length of the flowering period, panicle length, and primary production of fruits. The second involves panicle branching nodes where inhibition is permanent unless environmental factors favor development of secondary branches. Some available evidence supports the hypothesis that developmental regulation of both bud types is primarily hormonal rather than nutritional in nature.

11. Impact of Research on Science and General Public: This work will contribute knowledge which should be useful in the solution of the general problem of removing physiological limitations to plant productivity.

12. Obstacles to Achieving Objectives: Not enough technical assistance to accomplish the work rapidly.

13. Future Lines of Research for Emphasis: (1) Determine the roles of endogenous hormones in shoot, flower, fruit, and seed development. (2) Relate physiological activities, including photosynthesis and hormonal regulation of growth, to yield.

14. Facilities Needed: liquid scintillation counter
Personnel Needed: I currently have a post-doctoral assistant, Dr. Albert Huff, working on endogenous hormones in soybean flowers and fruits for a 1-year period. I need to have this position extended for an additional period of 2 to 5 years. I also need funds to support one graduate student to work on photosynthesis and other nutritional aspects of the problem.

15. Cooperation: Facilities -- South Dakota State University; Northern Grain Insects Research Lab (USDA)
Photosynthesis Studies -- S. Jensen and E. Gerloff, Northern Grain Insects Research Laboratory.

16. Titles and Places of Publications in the Past Two Years:
Dybing, C. D. Nutrition of the developing boll in flax. Agron. Abstr., p. 33. 1972.
Hovland, Aurora S. and C. D. Dybing. Cyclic flowering patterns in flax as influenced by environment and plant growth regulators. Crop Sci. 13:380-384. 1973.
Dybing, C. D., and R. A. Carsrud. Flax: Breaking the yield barrier. So. Dak. Farm and Home Res. 35(2):23-25. 1974.

17. Other Considerations: None.

18. Recommendations: Two things seem obvious: (1) USDA was criticized for not having enough research on photosynthesis; and (2) USDA responds by organizing a workshop on photosynthesis. This sells us a little short. There may be more to the physiology of yield than photosynthesis. In fact, USDA undoubtedly has programs going in other areas (one e.g.: mitochondrial "efficiency") which are meaningful. I recommend a workshop on the physiology of yield, not just on photosynthesis. Even if "photosynthetic efficiency" should prove to be the only factor limiting yield in a physiological sense, the inclusion of other areas of inquiry into a workshop should help to focus attention on the potential contribution of each area.

Prepared by William L. Ehrler Oct 1974

1. WRU 12260

2. U. S. Water Conservation Laboratory, Phoenix, Arizona 85040

3. William L. Ehrler, U. S. Water Conservation Laboratory, Phoenix Arizona 85040; AC 602 261-4356.

4. 1 SMY Working on Photosynthesis at this Location

5. 75%

6. Net Budget (1) Salaries $20,000 (2) Operations $500

7. Mission of Research: to conserve agricultural water supplies by improving the water-use efficiency (WUE) of crops

8. Objectives of Research: (1) to compare the WUE of a broad range of plant species exposed to drought in a controlled environment. (2) to measure both the stomatal and mesophyll resistances in an effort to ascertain which plant factors a plant breeder needs to emphasize in a program to improve WUE

9. Status of Present Research: (1) A plant chamber has been built to measure directly whole-plant transpiration, photosynthesis, leaf-water content, temperature, and indirectly leaf diffusion resistance and mesophyll resistance; (2) Experiments have been carried out to test the drought responses for the above parameters for intact plants of sorghum, corn, cotton, black-eyed pea, sunflower, mulberry, and jojoba (*Simmondsia chinensis* (Link) Schneider).

10. Significant Research Accomplishments: It was found that drought decreased both transpiration and photosynthesis the same percentage and thus did not improve the WUE. This fact indicates the predominance of stomatal over mesophyll resistance in controlling photosynthesis over the range of available water content.

11. Impact of Research on Science and General Public: Improvement of the WUE in agronomic species would permit greater crop production per unit of water transpired and consequently would lessen the impact of urban competition on agricultural water supplies.

12. Obstacles to Achieving Objectives: One difficulty is the nonuniformity to plant material. In certain instances a repetition of an experiment in the controlled environment room has given opposite results from the first time.

13. Future Lines of Research for Emphasis: Future tests will concentrate on desert plant species and will pay more attention to the solar radiation environment prevailing in the greenhouse during plant culture.

14. Research, Facilities, and Personnel Needs: A recording solarimeter and more soil psychrometers should be purchased. Ultimately a plant breeder should work cooperatively on this research.

15. Extent of Cooperation--Names of Persons and Institutions: Staff of the U. S. Water Conservation Laboratory

16. Titles and Places of Publications in the Past Two Years: None

17. Other Considerations: None

18. Recommendations: At least one other location should undertake similar research.

NATIONAL PROGRAM STAFF

Information for ARS Photosynthesis Workshop

Prepared by C. D. Elmore Date October 23, 1974

1. Number and Title of Work Reporting Unit (WRU). 7402-10590. Improved Cotton Varieties and Production Practices - production, distribution, and utilization of photosynthate during development of the cotton plant.

2. Location. USDA, ARS, Cotton Physiology Laboratory, Stoneville, Mississippi 38776.

3. Scientist's Name, Address, and Telephone Number. C. D. Elmore, P.O. Box 225, Stoneville, Mississippi 38776, 601/686-1110 FTS, extension 237.

4. Current SMYs Working on Photosynthesis at Your Location. Unknown.

5. Percent of Your Time Spent on Photosynthesis Research. 40%

6. Net Budget--(1) Salaries $23,500 (2) Operations $9,500

7. Mission of Research. To study the production, distribution and utilization of photosynthate in the cotton plant so that rate limiting steps and ways of modulation of these parameters may be discovered to improve yield, quality, and production efficiency of cottonseed and fiber.

8. Objectives of Research. To investigate patterns, paths and rates of translocation of photosynthate and nutrients in relation to the requirements of the developing fruit and the supply capacity of the leaf.

9. Status of Present Research. The role of the bract as a source of photosynthate is nearing completion. A study is underway to identify the amino acids in the various transport streams and to partition the nitrogen source for the developing boll between the Xylem (root) and Phloem (leaf). Work will begin shortly to correlate supply of photosynthate (photosynthesis) with fruiting.

10. Significant Research Accomplishments. The contribution of photosynthate to the boll by the bract was shown to be only 5% of the requirements of the boll at 20 days after flowering. At this same time Frego bracts are only 65% as productive as normal or nectariless bracts. Amino acids in the nectar were identified and quantitated (nectar is probably representative of native phloem).

11. Impact of Research on Science and General Public. This research benefits science by relating photosynthesis and translocation to total dry matter production and yield. The public benefits from this whenever such knowledge can be used to increase yield.

12. Obstacles to Achieving Objectives. Lack of a technician and isolation from other researchers in this area of study.

13. Future Lines of Research for Emphasis. Emphasis will be placed on studying the natural transport process and its relation to supply of photosynthate.

14. Research, Facilities, and Personnel Needs. Some technical help.

15. Extent of Cooperation--Names of Persons and Institutions.
B. L. McMichael, USDA, ARS, Cotton Physiology Lab, Stoneville, MS
B. W. Hanny, USDA, ARS, Cotton Physiology Lab, Stoneville, MS
W. P. Wergin, USDA, ARS, formerly of Southern Weed Science Lab, Stoneville, MS
J. D. Hesketh, USDA, ARS, Boll Weevil Lab, Starkville, MS

16. Titles and Places of Publications in the Past Two Years.
Elmore, C. D. 1973. Contributions of capsule wall and bracts to the developing cotton fruit. Crop Sci. 13:751-752.

Hanny, B. W. and C. D. Elmore 1974. Amino acids in cotton nectar. J. Ag. Fd. Chem. 22, 476-478.

Elmore, C. D. and J. Hacskaylo. 1973. Carbon 14 Tracer studies in dichotomous cotton plants. 1973 Beltwide Cotton Prod. Res. Conf. Proceedings. p 45. (abstract)

McMichael, B. L., C. D. Elmore, and J. Hacskaylo. 1973. The effects of foliar-applied nutrients on fruiting and growth characteristics of cotton. 1973 Beltwide Cotton Prod. Res. Conf. Proceedings. p 74. (abstract)

Elmore, C. D. and J. Hacskaylo. 1973. Some Source sink relationships in the cotton plant. Plant Physiol. supplement 51:62. (abstract)

Elmore, C. D. 1974. Further observations on $^{14}CO_2$ uptake and translocation by Cotton bracts. 1974 Abstracts Southern Branch American Society of Agronomy. p 6. (abstract)

Hanny, B. W. and C. D. Elmore 1974. Investigations of constituents and source of extrafloral nectar of cotton. 1974 Beltwide Cotton Prod. Res. Conf. Proceedings. p 46. (abstract)

Elmore, C. D. and B. L. McMichael. 1974. The occurrence of minerals in petiolar exudate of cotton. 1974 Agronomy Abstracts. p 71. (abstract)

17. Other Considerations. This project is not the study of photosynthesis *per se*, but rather involves the intricate and complex interrelationships occuring in the leaf, the developing fruit and in the phloem connecting them. This area is where little is known and much can be accomplished.

18. Recommendations. This area of research should be continued at least at present funding levels but with the addition of at least 1 technician.

controlling photosynthesis and transpiration in pubescent wheatgrass. In all other species, internal resistance to CO_2 fixation appeared to be the main factor limiting photosynthesis. Single leaf determination of photosynthesis for comparing clonal selection was variable and inconclusive.

11. Impact of Research on Science and General Public: Research on the physiology of forage plants is intended to provide information and methodology that will hasten the development of more productive grass varieties for beef cattle utilization. This goal is best pursued by obtaining information on factors such as photosynthetic and water use efficiency of species and clonal selections so that the most efficient lines can be used as parental material. It is becoming more evident that forages are going to be a major component in cattle feed rations in the future if we are to meet human food requirements.

12. Obstacles to Achieving Objectives: There is a lack of knowledge on the basic physiology of forage grasses, particularly the requirements necessary to initiate flowering and tiller development. Another major obstacle is the lack of professional and support staff (see item No. 14).

13. Future Lines of Research for Emphasis: Research emphasis will include obtaining information on physiological processes of forage grasses for increasing photosynthetic and water use efficiencies, photosynthetic variation in grass species, and on physiological processes as related to grassland management. Research approaches will involve studies to elucidate species and clonal differences in the role of stomates, water stress and biochemical mechanisms involved in controlling photosynthesis and transpiration and development of techniques to utilize physiological parameters for screening plants in a breeding project.

14. Research Facilities, and Personnel Needs: Laboratory facilities are adequate to support an increase in staff to work on the stated objectives. Presently, there is a shortage of greenhouse and headhouse space, but efforts are now under way to obtain additional greenhouses. There is a need for controlled environments chambers. However, our major needs are for professional and support personnel and adequate support funding. As a minimum, we need a physiologist with strong biochemical training, and a geneticist to increase our current research effort.

15. Cooperation: Whenever possible, research under the WRU will be conducted as part of a team approach involving physiologists, geneticists, agronomists and soil scientists working on related WRU's at Mandan.

ARS Photosynthesis Workshop

Prepared by A. B. Frank, Plant Physiologist October 24, 1974

1. WRU No. 16160. Improved plant varieties for forages.

2. North Central Region, Dakotas-Alaska Area, Northern Great Plains Research Center, Mandan, North Dakota.

3. A. B. Frank, Plant Physiologist
Northern Great Plains Research Center
Box 459
Mandan, North Dakota 58554
Phone: 701-663-6448

R. E. Barker, Research Geneticist
Northern Great Plains Research Center
Box 459
Mandan, North Dakota 58554
Phone: 701-663-6448

4. SMY: A. B. Frank 0.5 SMY (WRU 16160) 0.45 SMY on photosynthesis
R. E. Barker 1.0 SMY (WRU 16160) 0.05 SMY on photosynthesis

5. Percent of SMY on Photosynthesis:

A. B. Frank 90%
R. E. Barker 5%

6. Net Budget: (1) Salaries $18,000
(2) Operations $6,600

7. Mission of Research: To develop knowledge on the physiological processes of forage grasses to increase production through development of more efficient varieties and to aid in grassland management.

8. Objectives of Research: To determine plant physiological processes applicable to selection for improved forage grasses, to determine the photosynthetic variation in grass species, and to investigate plant physiological processes as they relate to grassland management.

9. Status of Present Research: Current research is directed toward obtaining a better understanding of photosynthetic efficiency and water relation of forage grasses. A recent study on the effects of ambient CO_2 concentration and light intensities on photosynthesis and diffusive resistance provided an assessment of the responsiveness of stomates and their impact on controlling rates of photosynthesis and transpiration. A current study involves the evaluation of clonal selections of several grass species for increased photosynthetic capacity.

10. Significant Research Accomplishments: Photosynthesis and transpiration rates of western wheatgrass *(Agropyron smithii)*, crested wheatgrass *(A. desertorum)*, pubescent wheatgrass *(A. intermedium* var. trichophorum), Russian wildrye *(Elymus junceus)*, orchardgrass *(Dactylis glomerata)*, and reed canarygrass *(Phalaris arundinacea)* were measured at three CO_2 levels and four light intensities to determine stomatal sensitivity to environmental factors. Stomates of pubescent wheatgrass had the most sensitivity to CO_2 and light. Results suggested that stomatal aperature was the main factor

16. Publications:

Frank, A. B. and R. E. Barker. 1974. Diffusive resistance and photosynthetic response of six grass species to CO_2 and light. Agron. Abst. 72. (Manuscript in draft form.)

Frank, A. B., J. F. Power, and W. O. Willis. 1973. Effect of temperature and plant water stress on photosynthesis, diffusion resistance, and leaf water potential in spring wheat. Agron. J. 65:777-780.

Barker, R. E., A. B. Frank, R. J. Lorenz, and J. F. Power. Variation of photosynthesis and water use in five range grasses. (To be presented at Society of Range Management Meetings, February 1975.)

17. Other Considerations: Some research involving photosynthesis has been conducted by A. B. Frank under WRU 16020. This research has not been discussed in this report other than listing a publication resulting from the work. Present plans for studies under WRU 16020 will not place any main emphasis on photosynthesis.

18. Recommendations: The nucleus of a research team is presently working on grass species improvement at Mandan. This team effort needs to be increased by additional staff and funding if the research objectives are to be achieved within a reasonable time period (see items 12 and 14). In addition, additional funds should be provided for technical support assistance, initial major equipment purchases, recurrent operation expenses, and greenhouse facilities. Also, there is a need for better coordination of photosynthesis research within ARS and consideration should be given to establishing a national "center of excellence" in photosynthesis research. However, present photosynthetic research projects should not be sacrificed at the expense of creating a national center. Instead, present projects should receive initial priority in receiving additional personnel and funds.

NATIONAL PROGRAM STAFF

Information for ARS Photosynthetic Workshop

1. WRU: 5510-10590-007

2. Location: Western Cotton Research Laboratory, Phoenix, Arizona.

3. Kenneth E. Fry, Western Cotton Research Laboratory, 4135 E. Broadway, Phoenix, Arizona 85040.

4. SMY: 1.0

5. 50% of time spent on growth and yield resulting from photosynthesis.

6. Budget: Salary $45,000 Operations: $10,000

7. Mission of Research: Search for plant factors and methods of field management that promote yield and efficient water use.

8. Objectives of Research:

   A) Characterize the influence of plant water stress on growth, development, and yield.

   B) Test and modify growth simulation models for use in local areas and scientific investigations.

9. Status of Present Research:

   A) A digital-voltmeter-computer system is being set up to acquisition field environment data and plant response parameters associated with growth and yield.

   B) The non-destructive and simple stem diameter measurements are being used to index plant leaf area and shoot dry weight in field plots. This method is being used in growth analysis and computer model verification.

   C) Environmental and plant data are being collected from data banks and field apparatus to test and modify established growth simulation models.

10. Significant Research Accomplishments:

   A) Computer programs were developed to simulate leaf water potentials between 0600 and 2000 hrs for each day after irrigation as based on periodic afternoon bomb pressure readings. Daily integrated stress-hours above a threshold were found to correlate with decreasing lint yields (r = .90).

B) The sigmoid growth curves of stem cross section areas (from stem diameters), plant leaf area, and shoot dry weight show that vegetative growth and boll development are reduced early in the fruiting season where less than optimum moisture conditions prevail.

11. Impact of Research on Science and General Public: Characterizing the responses of plant factors to environmental stresses is useful in developing computer simulation programs. Increasing plant water use efficiency is beneficial to the grower and consumer.

12. Obstacles to Achieving Objectives: Obtaining suitable field plots for irrigation treatments and data acquisition may sometimes be a problem.

13. Future Lines of Research and Emphasis: Test and modify growth simulation models with emphasis on using input parameters that have the greatest influence on yield in the local area of irrigated semi-desert.

14. Research Facilities and Personal Needs: General adequate.

15. Extent of Cooperation: Dr. David Kittock, Cotton Research Center, Phoenix; Dr. William Ehrler, Water Conservation Laboratory, Phoenix.

16. Publications in Preparation:

A) Simulated leaf stress-hours in semi-desert climate and cotton yield.

B) Stem diameter as an index to plant leaf area and shoot dry weight in cotton.

NATIONAL PROGRAM STAFF

Information for ARS Photosynthesis Workshop

Prepared by M.H. Gaskins Date November 6, 1974

1. 7602-10810 Humid Pasture Production Practices.

2. Gainesville, Florida.

3. M.H. Gaskins
USDA-ARS
Department of Agronomy
304 Newell Hall
University of Florida
Gainesville, FL 32611
FTS (904) 377-3250

4. About 0.25 SMY.

5. About 10 %.

6. Budget for this work about $10,000 for salaries and $2,000 for operations.

7. Improve efficiency of forage crops.

8. Identify genotypes of tropical grasses which maintain photosynthetic capability under stress.

9. Some lines of *Chloris* have given superior performance. The study is not complete.

10. Have shown that daylength sensitivity is highly important, but often ignored by breeders, in improving capability of forage grasses in Florida to sustain high yields past the mid-summer peak growth season.

11. Pasture productivity in Florida is a significant obstacle to increasing beef and dairy production. More efficient cultivars definitely are needed.

12. Project is not adquately funded.

13. Detailed study of metabolic processes inhibited by stress conditions, and the role of growth hormones in regulating environmental responses.

14. Facilities are adequate. Funds are needed for various items of equipment, and for addition of one SMY to the project.

15. All forage crops investigators in the Agronomy Department, University of Florida, are active or potential professional cooperators.

16. i. Carter, J.L., L.A. Garrard and S.H. West. 1972. Starch degrading enzymes of temperate and tropical species. Phytochemistry 11:2423-2428.

    ii. Carter, J.L., L.A. Garrard and S.H. West. 1973. Effect of gibberellic acid on starch degrading enzymes in leaves of *Digitaria decumbens*. Phytochemistry 12:251-254.

    iii. Carter, J.L., L.A. Garrard, and S.H. West. 1974. Amylolytic activity of Orchardgrass and starch and sucrose contents of Orchardgrass vs Pangola Digitgrass leaf blades as influenced by night temperature and gibberellic acid. Crop Science. 14:384-387.

    iv. Gaskins, M.H. and D.A. Sleper. 1974. Photosensitivity of some tropical forage grasses in Florida. Proc. Soil and Crop Sci. Soc. Fla. 33:20-21.

PHOTOSYNTHESIS RELATED RESEARCH

Prepared by: Gene Guinn　　　　　　　　Date: October 21, 1974

1. WRU Number: 5510-10590-008 Improved cotton varieties and production practices - Metabolites involved in flowering and fruiting as modified by environment.

2. Location: Western Cotton Research Laboratory, Phoenix, Arizona.

3. Scientist: Gene Guinn, 4135 E. Broadway, Phoenix, AZ 85040, Phone AC 602-261-3524.

4. SMY's: One

5. Percent of Time Spent on Photosynthesis: About 10%. Much of my work is related to, but is not directly on, photosynthesis.

6. Budget: Salaries: $36,000　　Operations: $10,000.

7. Mission: The mission is to investigate the effects of environment on metabolites involved in flowering and fruiting of cotton.

8. Objectives of Research:

    A. Study mechanisms by which stresses induce abortion of small squares and abscission of older squares and young bolls.

    B. Investigate factors that influence the partitioning of metabolites between vegetative and reproductive development.

    C. Investigate factors that affect starch synthesis and breakdown, and determine if, and to what extent, starch accumulation in chloroplasts inhibits photosynthesis.

9. Status of Present Research: We are currently investigating:

    A. The influence of brief periods of dim light on sugar content, membrane integrity, ethylene evolution, and shedding of young bolls.

    B. The effects of moisture stress on ATP levels, sucrose and starch breakdown, and transport of sugars from leaves to young bolls.

10. Significant Research Accomplishments:

    A. Factors that decreased photosynthesis or increased respiration (dim light, short days, warm nights) decreased sugar content of young bolls, increased their rate of ethylene evolution, and increased their rate of abscission.

B. The combination of high CO_2, bright light, and long days caused excessive accumulation of starch in leaves, decreased ATP content, and hastened senescence of leaves.

C. Procedures were developed for purification of nucleotides and assay of ATP.

D. Moisture stress caused a drastic decrease in ATP content of leaves and also caused a gradual decrease in sucrose and starch content of leaves, but increased fructose and glucose content of leaves.

11. Impact of Research on Science and General Public: A better understanding of how environmental factors interact to affect photosynthesis and the partitioning of metabolites between vegetative and reproductive development should contribute to more efficient cotton production and add to basic knowledge of fruiting and abscission processes.

12. Obstacles to Achieving Objectives: None

13. Future Lines of Research for Emphasis:

A. Determine effects of boll load, short days, warm nights, and crowding on metabolite composition (sugars, starch, fatty acids, amino acids, nucleotides, and ATP) of leaves, squares, and bolls; and effects of above on hormones (auxin, abscisic acid, and ethylene) in, and abscission of, squares and young bolls.

B. Investigate factors that affect starch synthesis and breakdown, and determine effects of starch accumulation in leaves on photosynthesis.

C. Determine effects of moisture stress on photophosphorylation, synthesis and breakdown of sucrose and starch, and translocation of sugars to developing bolls.

14. Needs: Part-time helper to clean glassware and assist technician.

15. Cooperation: University of Arizona provides farm land and cultural practices for growing cotton in field experiments.

16. Publications:

1. Guinn, Gene and Marie P. Eidenbock. 1972. Extraction, purification and estimation of ATP from leaves, floral buds, and immature fruits of cotton. Anal. Biochem. 50: 89-97.

2. Guinn, Gene. 1973. Purification of leaf nucleotides and nucleosides on insoluble polyvinylpyrrolidone. Anal. Biochem. 54: 276-282.

3. Guinn, Gene. 1973. Effects of low light intensity on some constituents of young cotton bolls. Proc. 1973 Beltwide Cotton Production Research Conference, pp. 39-41.

4. Guinn, Gene. 1974. Abscission of cotton floral buds and bolls as influenced by factors affecting photosynthesis and respiration. Crop Sci. 14: 291-293.

Prepared by John D. Hesketh   Date Dec. 6, 1974

1. WRU No. 7502-12330-001. Title: Optimization of Soil-Plant-Meteorlogical Factors for Plant Growth.

2. Mississippi State, MS. 39762.

3. John D. Hesketh, Cotton Production Research, P.O. Box 5367, Mississippi State. 601-323-2230.

4. Current SMY's working on Photosynthesis: Harry Lane, 0.1; A.C. Thompson, 0.1, J. W. Jones, 0.1; J. M. McKinion, 0.1; J. D. Hesketh, 0.4; all on photosynthetically-related research including leaf area expansion; all unofficially; totally 0.8 SMY's excluding D.N. Baker's effort.

5. 40% photosynthetically-related research (interactions between the photosynthetic process and other plant physiological processes).

6. Net Budget (This WRU, Hesketh only) (1) Salaries $27,050. (2) Operations $3870.

7. Optimize efficiency of production, energy use, for maximum farm profit and minimum energy use and pollution. Optimize production *per se*.

8. Optimize soil-plant-meteorological factors for plant growth utilizing simulation modeling techniques. Develop research techniques for acquiring necessary information for model construction and interfacing.

9. Research status: Considering our limited resources, everything has gone exceptionally well. We have been forced to pool resources and cooperate closely behaving as technicians in our appropriate specialties to do what we have done, resulting in many authors on our papers. Also we have been fortunate that some rather large scale and ambitious experiments have produced some interesting results. Also we have been fortunate in developing some mathematical manipulations that have had quite an impact on our research and model-construction efforts.

10. Accomplishments: The cotton plant growth models. A boll weevil eradication model. Effects of CO_2 enrichment and N-fertility on plant reserves and photosynthesis. Exploitation of phytotron techniques for generating information for constructing plant growth models. Effects of CO_2 enrichment on floral initiation. Photoperiod control of flowering among cotton, soybean and sorghum varieties.

11. Plant growth models were needed for development of insect models in the Insect Pest Management modeling effort. Also were needed by agriculture engineers and economists developing farm management models. CO_2-fertilization practices in the S.W. and similar areas of the world using greenhouse culture in light-rich environments will be affected by our findings. Hopefully we set some good examples for team research and construction of biological models focusing on national problems.

12. Financial support. Inter-institutional rivalries. Negativism among experimentalists towards modeling at other locations.

13. Nitrogen and carbohydrate budgets in plants, leaf expansion in plants, effects of both on predicting plant photosynthetic supply, sink effects on photosynthesis, metabolic aspects of organogenesis.

14. Need graduate students, post-docs, special photosynthetic equipment, travel money to get to controlled environment facilities, development elsewhere of better controlled environment facilities for use by ARS personnel for in depth environment-plant studies, computer equipment.

15. Besides local coworkers listed above, personnel at Duke Univ., and the two cotton physiology laboratories (H. Hellmers, D. Elmore, J. Mauney and their co-workers).

16. Paraphrased titles and places of published papers 1973-74. Phytotron information for modeling soybean growth, Crop Sci. Carbon dioxide release in the field-two papers, Agron. J. CO_2 enrichment and floral initiation. Environ. Control Biol. Systems. System I and II chlorophyll units in mutants grown at different temperatures, PNAS. Aspects of predicting gross photosynthesis for plant models, Biophysical Ecology. Phytotronics and modeling tree growth, N.Z. Developmental Physiology Symposium. Cotton Physiology, L.T. Evans'book. Literature base for modeling photosynthesis, growth, nitrogen metabolism, two papers, Proc. Beltwide Cott. Prod. Res. Confs. Crop Architecture, U.S. Gupta's book. Modeling photosynthesis, respiration, carbohydrate reserves, carbohydrate incorporation into plant tissue; photosynthesis and reserves in soybeans; two papers, Belgium Photosynthesis Symposium. Phytotrons and modeling plant growth, Poland Hort. Cong. Predicting leaf expansion in a plant; predicting populations of floral parts, two papers, Beltwide Cott. Prod. Res. Confs. Nitrate reductase activity; soluble and insoluble-stored sugars (actual buildup of 45-55% in leaves, a field N-trial, 1974), two papers, ibid. Continuous computer simulation of all the above, approved for pub. Nitrogen in plant parts in a N-fertility trial, in manuscript form. Farm management modeling problems, Agr. Eng. Preprint. Water stress and soybean growth, Plant Dis. Rept.

17. The mechanism for meeting manuscript deadlines hasn't always been satisfactory, although the Nat'l Eds. have done a marvelous job in this respect.

18. Whatever ARS administrative problems and philosophy may be, we need an easy mechanism for acquiring graduate students and post-docs. At the bench level and one administrative layer above, the formal administrative chain needs to be relaxed to enhance team research on prespecified problems in a spontaneous, informal manner. Need better methods for evaluating and rewarding individuals involved in team research; need to eliminate team leaders credited with results from their teams and who over-direct team activities. The Miss. State group, Cott. Prod. Res., has been experimenting in setting up team efforts, and Rex Colwick and David Ranney have been innovative in relaxing administrative procedures to allow for cooperation among individuals in the group.

ARS Photosynthesis Workshop

Prepared by James E. Irvine Date October 16, 1974

1. Number and Title of Work Reporting Unit (WRU)
   501-7412-10730 Sugarcane Production Research

2. Location
   U.S. Sugarcane Laboratory, Houma, Louisiana

3. Scientist's Name, Address, and Telephone Number
   James E. Irvine, U.S. Sugarcane Laboratory, Box 470, Houma, Louisiana 70360

4. Current SMYs Working on Photosynthesis at Your Location
   1/4

5. Percent of Your Time Spent on Photosynthesis Research
   1/4

6. Net Budget--(1) Salaries $8,000 (2) Operations $1,500

7. Mission of Research
   Increased production of sugar per acre

8. Objectives of Research
   To improve the photosynthetic efficiency of sugarcane through breeding or improved cultural practices.

9. Status of Present Research
   The relation of variety differences to boundary layer thickness is being investigated. When completed, work on variety differences in rates of photosynthesis per unit area will be phased out. Research is being focused on the development of the maximum effective leaf area index for sub-tropical sugarcane. Since the length of the photosynthetic period for the crop appears to affect yield more than the varietal rate of photosynthesis per unit area, work has been initiated which involves the incorporation of the rapid expansion of leaf area in sorghum with the long photosynthetic period of cane.

10. Significant Research Accomplishments
    Demonstration of variety differences in rate of photosynthesis per unit area.
    Demonstration of decreased respiratory CO_2 evolution with increased photosynthesis, probably due to internal recycling.
    Stomatal aperatures decrease with increasing wind speed, although photosynthesis increases.
    Of the diseases affecting sugarcane in Louisiana, only certain strains of mosaic reduce photosynthesis; rates are not related to symptom severity.
    Rates of photosynthesis are related to several leaf characters, but are not related to yield; leaf area index is closely related to yield.

11. Impact of Research on Science and General Public
The recognition that sugarcane yields in Louisiana were limited by a low leaf area index and a short photosynthetic period, lead to support of an agronomic program designed to improve row geometry. Up to 30% increases in yields have been attained, and improved spacing is gradually being adopted by growers.

12. Obstacles to Achieving Objectives
Lack of time and sub-professional assistance.

13. Future Lines of Research for Emphasis
a. Determine optimum canopy for different row geometries.
b. Determine practicality of *Saccharum*-sorghum hybrids for increased leaf expansion rate.

14. Research, Facilities, and Personnel Needs
Sub-professional assistant GS-7

15. Extent of cooperation
T. A. Bull, C.S.R., Brisbane, Australia
H. Rostron, Mt. Edgecombe, S. Africa
Cooperation is limited to determination of the effect of Polaris (sugarcane ripener) on photosynthesis.

16. Titles and Places of Publications in the Past Two Years
Irvine, J. E. 1973. Estimating the total leaf area in sugarcane. Proc. ASSCT 3(NS):121-123.
__________ 1972. Photosynthetic rate in sugarcane: effect of virus diseases, genetic disorders, and freezing. Proc. ISSCT 14:1131-1138.
__________ 1972. Canopy characters and their relation to the yield of sugarcane varieties. Proc. ASSCT 2(NS):73-75.
__________ 1974. The relations of leaf and canopy characters to photosynthetic rates and yields of sugarcane varieties. Submitted to Crop Science.

17. Other Considerations - - - -

18. Recommendations
ARS has the ability to develop a program for photosynthetic research that would be unequaled for excellance. Such a program should be developed, covering ecological, biophysical and biochemical aspects, but with the ultimate goal of improving photosynthetic efficiency in crops. In addition to recruiting superior personnel for the project, ARS should identify and give maximum support to its outstanding workers, allowing them to pursue research goals of their choice at locations conducive to maximum success. A small committee could easily identify both promising workers and lines of research.

NATIONAL PROGRAM STAFF

Prepared by Stanley G. Jensen Date October 30, 1974

1. Number and Title of Work Reporting Unit (WRU): 12060 Biology-Plant Diseases and Nematodes

2. Location(s): Brookings, SD

3. Scientist's Name, Address, and Telephone Number:
S. G. Jensen
Northern Grain Insects Research Laboratory
RR #3
Brookings, SD 57006
Telephone: 605-693-3241

4. Current SMYs Working on Photosynthesis at Your Location: 0.35

5. Percent of Your Time Spent on Photosynthesis Research: 25%

6. Net Budget--(1) Salaries $8300.00 (2) Operations $1600.00

7. Mission of Research: Agricultural production efficiency

8. Objectives of Research: Determine the pathogenesis of arthropod transmitted viruses of small grains and interpret the findings in terms of the nature of disease resistance and the physiological, cytological, or morphological basis of yield loss.

9. Status of Present Research: The past program of photosynthesis research is being continued with cereal-infecting viruses and the relationship between disease, and stomatal aperature, and photosynthesis. We are continuing investigations on the rate of utilization of translocated photosynthate in healthy and diseased plants.

10. Significant Research Accomplishments: (A) We have described in detail the photosynthetic rates of the various tissues of cereal grains from the early seedling stage through to maturity. (B) Photosynthetic efficiencies of the flag leaf, leaf sheath, stem, and head have been compared for several varieties of wheat. (C) Data has been collected which shows the integration of photosynthesis with other physiological factors such as respiration, dry weight, chlorophyll, etc. (D) In a detailed comparison of the photosynthesis of different varieties of wheat, it has been shown that significant differences occur only between widely divergent germplasms. (E) A comparison of different cereals shows a divergence in the rate of translocation and utilization of photosynthate. (F) All of these studies have been done in a comparison between barley yellow dwarf virus-infected plants and the comparable healthy tissue.

11. Impact of Research on Science and General Public: (A) To a virologist or physiologist, these investigations point up the impact of a systemic

virus on the physiology of a plant with possible explanations for such symptoms as chlorosis, stunting, and a poor yield. (B) A comparison of the photosynthetic rates of the upper portion of the plant may provide an explanation for some of the higher yield potential of the semi-dwarf wheats. (C) The integration of photosynthesis with other physiologic factors provides a partial description of the complexity of the interactions in different tissues and provides a framework for model builders who would develop a computerized physiologic system. (D) The affects of BYDV on the translocation and utilization of photosynthate has significance for pathologists but the technique may also have relevance for physiologists who are attempting to seek out higher efficiency plants.

12. Obstacles to Achieving Objectives: (A) Many of the objectives of this research program are not compatible with the theme of the photosynthesis workshop. (B) The amount of work accomplished is directly related to the number of hands and machines available to do the work.

13. Future Lines of Research for Emphasis: (A) Future research will emphasize the relationship between stomatal aperature and rates of photosynthesis. (B) Further studies will be conducted on the rate of translocation and utilization of photosynthate, particularly with viruses other than BYDV.

14. Research, Facilities, and Personnel Needs: My research effort could operate much more efficiently if I had greater assistance in rearing the insect vectors of the viruses which I study and greater assistance in the preparation of samples for physiologic work.

15. Extent of Cooperation--Names of Persons and Institutions: None.

16. Titles and Places of Publications in the Past Two Years:

Jensen, S. G., P. J. Fitzgerald, and J. R. Thysell. 1971. Physiology and Field Performance of Wheat Infected with Barley Yellow Dwarf Virus. Crop Sci. 11:775-780.

Jensen, S. G., and J. W. VanSambeek. 1972. Differential effects of barley yellow dwarf virus on the physiology of tissues of hard red spring wheat. Phytopathology 62(2):290-293.

Jensen, S. G. 1973. Some effects of barley yellow dwarf virus on photosynthesis translocation and utilization in barley. Abst. Sec. Int'l. Congress Plant Path.

17. Other Considerations: No comment.

18. Recommendations: I agree with the concept and usefulness of this workshop and wholeheartedly support its aims and goals. I would recommend that plant physiologists who study normal plant physiology should give more attention to publications in pathologic physiology. In each case, the controls constitute a normal situation and I have found that a wealth of such data is being overlooked by physiologists.

ARS Photosynthesis Workshop

Prepared by: Russell J. Kohel Date: October 30, 1974

1. Number and Title of Work Reporting Unit (WRU): 7302-10591, Improved cotton varieties and production practices (Genetics, Breeding, and Taxonomy of Cotton Germplasm).

Project: Genetics, Cytogenetics of Cotton Germplasm.

2. Location: College Station, Texas.

3. Scientist's Name, Address, and Telephone Number:

Russell J. Kohel
Agronomy Field Laboratory
Texas A&M University
College Station, Texas 77843
(713) 846-8821, Ext. 311

4. Current SMY's Working on Photosynthesis at Your Location:

.1 SMY ARS and .2 SMY State

5. Percent of Your Time Spent on Photosynthesis Research: 10%

6. Net Budget--(1) Salaries $5,000 (2) Operations $1,000

7. Mission of Research: Improve efficiency of crop production through plant developmental studies.

8. Objectives of Research: To determine photosynthetic carbon metabolism in relation to crop efficiency in cotton.

9. Status of Present Research: Research is currently directed toward measuring the energy trapped and its conversion to harvestable commodities.

10. Significant Research Accomplishments: Characterized the developmental properties of virescent and chloroplast mutants in cotton. Characterized the photosynthetic pools and their translocation to seed and fiber.

11. Impact of Research on Science and General Public: The results of this research is directed toward supplying information to applied scientists so that new management practices can be implemented or genetic modifications can be employed to improve the plant and crop efficiency.

12. Obstacles to Achieving Objectives: The total program is understaffed professionally. Its development requires additional staffing and associated support and facilities.

13. Future Lines of Research for Emphasis: Continuation of the current lines of research are planned, but the program needs to be expanded with additional funds and personnel. To determine environmental and genetic variation and potential for modification will require large scale replicated experiments.

14. Research, Facilities, and Personnel Needs: Professional and technical staff should be added to support 1 SMY. This effort would enable the establishment of a cooperative interdisciplinary program with the cotton research group. Facility needs include construction of the glasshouse planned in the original construction of our headhouse complex, and updating and renovating of our current greenhouse facilities.

15. Extent of Cooperation--Names of Persons and Institutions: This program is a cooperative program with C. R. Benedict, TAES.

16. Titles and Places of Publications in the Past 2 Years: (See attached list).

17. Other Considerations: This program is being developed as part of an interdisciplinary team in the Basic Cotton Genetics Center at College Station, Texas. The utilization of the interdisciplinary team brings more viewpoints to focus on the problems and enables a more rapid translocation of basic research results to the applied scientists. This is a federal-state cooperative program that needs support through in-house and extramural support.

18. Recommendations: Increase the program funding and increase 1 SMY and technician. Build glasshouse. In the interim, provide funds for extramural support of current program.

DEVELOPMENTAL GENETICS PUBLICATIONS OF R. J. KOHEL & C. R. BENEDICT

Benedict, C. R., and R. J. Kohel. Characteristics of a virescent cotton mutant. Plant Physiol. 43:1611-1616. 1968.

Benedict, C. R., and R. J. Kohel. Effect of nucleus on chloroplast development in cotton leaves. Proc. Beltwide Cott. Prod. Res. Conf. (Abstract). 1968.

Kohel, R. J. Effects of genotypes and heterozygosity of pollen source and method of application of pollen on seed set and fiber development in cotton. Crop Sci. 8:293-295. 1968.

Kohel, R. J., and C. R. Benedict. Variegated cotton mutant: Physiological functions of mutant chloroplasts. Agron. Abst., p. 12 (Abstract). 1968.

Benedict, C. R., and R. J. Kohel. Photosynthetic rate of virescent cotton mutant lacking chloroplast grana. Plant Physiol. 45:519-521. 1969.

Benedict, C. R., and R. J. Kohel. The synthesis of ribulose-1,5-diphosphate carboxylase and chlorphyll in virescent cotton leaves. Plant Physiol. 44:621-622. 1969.

Benedict, C. R., R. J. Kohel, and D. L. Ketring. Nuclear control of plastid development. Proc. Amer. Inst. Biol. Sci. (Abstract). 1970.

Benedict, C. R., and R. J. Kohel. Carbohydrate and fiber synthesis. Proc. Beltwide Cott. Prod. Res. Conf. (Abstract). 1971.

Benedict, C. R., R. J. Kohel, D. L. Ketring, and K. M. McCree. Genetic control of chloroplast development. Proc. Tex. Acad. Sci. (Abstract). 1971.

Kohel, R. J., and C. R. Benedict. Description and metabolism of aberrant and normal chloroplasts in variegated cotton, *Gossypium hirsutum* L. Crop Sci. 11:486-488. 1971.

Alberte, R. S., J. S. Hesketh, A. W. Naylor, R. Bernard, J. Endrizzi, R. Kohel, M. Zuber. Chlorophyll mutants of cotton, soybean, and corn chlorophyll distribution and photorespiratory behavior. Agron. Abst., p. 29 (Abstract). 1972.

Benedict, C. R., K. M. McCree, and R. J. Kohel. Photosynthetic rate of a chlorophyll mutant of cotton. Plant Physiol. 49:968-971. 1972.

Benedict, C. R., R. H. Smith, and R. J. Kohel. Physiological synthesis and growth measurements of lint and seed in developing cotton bolls. Proc. Beltwide Prod. Res. Conf., p. (Abstract). 1972.

Kohel, R. J., and C. R. Benedict. Plastom control of chloroplast development in cotton, Gossypium hirsutum L. Crop Sci. 12:343-346. 1972.

Benedict, C. R., J. D. Hall, and R. J. Kohel. Transport of ^{14}C-photosynthate from source leaves to different aged cotton boll sinks. Proc. Beltwide Prod. Res. Conf., p. (Abstract). 1973.

Benedict, C. R., and R. J. Kohel. The efficiency of the conversion of photosynthate to harvestable commodities seed and lint in cotton plants. Agron. Abst., p. 29 (Abstract). 1973.

Benedict, C. R., and R. H. Smith, and R. J. Kohel. Incorporation of carbohydrate into developing cotton bolls, Gossypium hirsutum L. Crop Sci. 13:88-91. 1973.

Kohel, R. J., and C. R. Benedict. Fiber elongation and dry weight changes in mutant lines of cotton. Agron. Abst., p. 21 (Abstract). 1973.

Schubert, A. M., C. R. Benedict, J. D. Berlin, and R. J. Kohel. Cotton fiber development - Kinetics of cell elongation and secondary wall thickening. Crop Sci. 13:704-709. 1973.

Benedict, C. R., and R. J. Kohel. The efficiency of conversion of photosynthate to harvestable commodities seed and lint. Proc. Beltwide Cott. Prod. Res. Conf. (Abstract). 1974.

Kohel, R. J., J. E. Quisenberry, and C. R. Benedict. Fiber elongation and dry weight changes in mutant lines of cotton, Gossypium hirsutum L. Crop Sci. 14:471-474.

Kohel, R. J., J. E. Quisenberry, and C. R. Benedict. The growth and development of cotton fibers. II. Genetic mutants. Proc. Beltwide Cott. Prod. Res. Conf. (Abstract). 1974.

Quisenberry, J. E., R. J. Kohel, and C. R. Benedict. The growth and development of cotton fibers. III. Environmental variation. Proc. Beltwide Cott. Prod. Res. Conf. (Abstract). 1974.

Benedict, C. R., R. J. Kohel, and A. M. Schubert. Kinetics of ^{14}C-photosynthate translocation in cotton plants. Plant Physiol. Suppl. p. 67 (Abstract). 1974.

Schubert, A. M., C. R. Benedict, R. J. Kohel, and J. E. Quisenberry. The growth and development of cotton fibers. I. Upland and Pima cottons. Proc. Beltwide Cott. Prod. Res. Conf. (Abstract). 1974.

PHOTOSYNTHESIS WORKSHOP

Prepared by J. R. Mauney   Date 9-15-74

1. WRU Number: 5402-10590-005 - Improved Cotton varieties and production practices - Effects of environment on the flowering responses of cotton.

2. Location: Western Cotton Research Laboratory, Phoenix, AZ 85040
(602) 261-3524

3. Name: J. R. Mauney and L. L. H. Pinkas, 4135 East Broadway,
Phoenix, AZ 850 0

4. SMY: 1.5

5. Budget: Salaries $75,000   Operating $20,000

6. Mission of Research: Determine which environmental factors influence the flowering and fruiting patterns and efficiency of cotton.

7. Objectives of Research: Two approaches are used in this work. First, is to monitor the field environment and observe correlations with plant performance. The objective is to select patterns of environmental stress which seem to be causing delayed flowering or unusually heavy fruit shed. The second approach is to engineer artificial environments to test the specific effects of individual factors. This necessitates developing the equipment needed to produce optimum light and temperature control systems. The objective is to specify the exact factors in complex environments which are limiting the productivity of the plant. When these factors are known we can attempt to alleviate their effects through cultural or chemical treatments.

8. Status of Present Research: High temperature particularly at night has been found to adversely affect both flower initiation and square and boll retention. However, this effect seems to be modified by many other factors including sunlight, prior temperatures, carbon dioxide concentration, plant maturity, genetic variety, and applied pesticides. An almost limitless series of interactions appears to exist within the permutations and combinations of these factors. We need to find the common thread which links them together. Starch manufacture and degradation may be this link. In CO_2 enriched atmosphere plants retain more flowers and fruit. At the same time they manufacture excessive amounts of starch. A research grant from this project to Dr. Jensen, University of Arizona, has shown that starch catabolism is not subject to product feed-back control as is other carbohydrate breakdown.

Dr. Pinkas resigned November 1973 and will not be replaced. His equipment is being used by others.

9. Significant Research Accomplishments:

a. Established that temperature above 40°C at sunset or that remain above 28°C at night inhibited flower formation and retention in both upland and Pima cottons.

b. In atmosphere enriched with CO_2 and optimum temperature and light conditions plants retained slightly more flowers and fruit, but produced excessive amounts of leaf starch.

c. Applications of methyl parathion to plants at flowering stage had no significant effect on flower and boll retention.

d. A computer controlled data acquisition system to monitor environmental factors was set up and programmed.

e. Suspensions of separated cells from cotton leaves are capable of active photosynthesis. The degradation of starch in these cells does not respond to product concentration controls.

10. Impact of Research on Science and General Public: Cotton is a typical example of plant inefficiency. Any steps which we take to discover the causes of inefficiency in cotton will not only increase production and lower costs of production of lint but also give clues about how to increase efficiency of plants with similar growth characteristics, i.e. soybeans.

11. Obstacles of Achieving Objectives: As stated in (7) above the sheer complexity of the interactions encountered are a major reason why objectives are difficult to achieve. Personnel ceilings, procurement difficulties, and administrative red tape in general take time and energy away from productive work.

12. Future Lines of Research for Emphasis: The possibility of using starch content as a guide to the effects of environment on productivity will be looked at further. Growth chamber work with abnormal environments will be used to determine if starch content is always correlated with lint productivity methods of increasing starch utilization in dark will be sought.

13. Research, Facilities, and Personnel Needs: Expansion of Growth Chamber facility is needed and will be probably be constructed.

14. Cooperation: University of Arizona Cotton Research Center; Dr. Richard Jensen, Chemistry Department, University of Arizona; Dr. Jack Downs, N.C. State University.

15. Recommendation: Heavier emphasis should be placed in ARS on and less on the organizational structure.

17. Number of Publications: Four

Information for ARS Photosynthesis Workshop

Prepared by: D. E. Moreland Date: November 15, 1974

1. Title: Mechanisms of Herbicide Action - WRU: 7802-12070

2. Location: Raleigh, N. C.

3. Scientist: D. E. Moreland
U.S.D.A., A.R.S.
Crop Science Department
N. C. State University
Raleigh, N. C. 27607
Telephone: 919-737-2661 Comm.
919-755-4408 FTS

4. Current SMYs Working on Photosynthesis at Location: 0.

5. Percent of Time Spent on Photosynthesis Research: 5.

6. Net Budget--(1) Salaries_________ (a) Operations________

7. Mission of Research: To conduct basic research on weed biology and mechanisms of control.

8. Objectives of Research: To identify mechanisms of action and selectivity at the cellular and molecular levels involved in the expression of phytotoxicity by herbicides.

9. Status of Present Research:

   Studies are being continued to identify specific sites on the electron transport and energy generation pathways in isolated mitochondria and chloroplasts that are affected by herbicides.

   Action of herbicides known to interfere with ATP production in isolated mitochondria and chloroplasts is being studied on adenylate metabolism in germinating seed, seedlings, and foliar tissue of mature plants.

10. Significant Research Accomplishments:

    A number of herbicides have been identified that interfere with electron transport and phosphorylation in isolated mitochondria or chloroplasts, or in both organelles.

    Herbicides were identified that inhibit nucleic acid and protein syntheses.

    Inhibitors of oxidative phosphorylation have been shown to decrease ATP levels in excised plant tissue and in germinating seed.

11. Impact of Research on Science and General Public:
Many of the currently used herbicides interfere with photosynthesis, a process unique to green plants, hence, they are relatively nontoxic to nontarget organisms.
Largely based on some of our structure-activity studies with isolated chloroplasts, many commercial companies, especially those in Europe and the United Kingdom, evaluate the action of candidate herbicides against reactions mediated by isolated chloroplast.

12. Obstacles to Achieving Objectives:
Progress is limited by a lack of comprehension of growth and the factors through which it is controlled at the biochemical or molecular level.
Other than the effects on chloroplast and mitochondrial systems, which do appear to correlate with *in vivo* responses, relatively few definitive studies document the mechanism of action of other herbicides. For the most part, the extent to which a given herbicide may interact with different enzymes, the relative contributions of these interactions to growth, and the many chemical and physical factors that underly inhibition are unknown.

13. Future Lines of Research for Emphasis:
There are many herbicides that do not affect ATP generation. Hence, there is a need for identifying biochemical mechanisms affected by those herbicides that do not interfere with photosynthesis and respiration.

14. Research, Facilities, and Personnel Needs:
Facilities and research support adequate unless large pieces of equipment become necessary to achieve future objectives.
There is a continuing need for well-trained technicians and junior scientists to follow through on ideas that are generated.

15. Extent of Cooperation -- Names of Persons and Institutions:
All of our research is conducted cooperatively and support, in addition to that received from ARS, is provided by U. S. Public Health Service research and graduate training grants, and CSRS grants.
Individuals involved in cooperative studies include:
J. L. Hilton and J. B. St. John, ARS, USDA, Beltsville, Maryland.
M. R. Boots, Medical College of Virginia, Richmond, Virginia.
M. Wilcox, University of Florida, Gainesville, Florida.
G. G. Still, Metabolism Laboratory, ARS, USDA, Fargo, North Dakota.
A. D. Worsham and F. T. Corbin, N. C. State University, Raleigh.

16. Titles and Places of Publications in the Past Two Years: See attached listing.

17. Other Considerations:
Our studies have not been related directly to the area of photosynthetic efficiency. Instead, attention has been focused on how herbicides affect the photochemical reactions of isolated chloroplasts and interfere with the bioenergetics of plant growth and development.

Recent Publications

1. Guthrie, F. E., P. V. Shah, and D. E. Moreland. 1974. Effects of pesticides on active transport of glucose through the isolated intestine of the mouse. J. Agr. Food Chem. 22:713-715.

2. Moreland, D. E., G. G. Hussey, and F. S. Farmer. 1974. Comparative effects of dichlobenil and its phenolic alteration products on photo- and oxidative phosphorylation. Pestic. Biochem. Physiol. 4:356-364.

3. Moreland, D. E., G. G. Hussey, C. R. Shriner, and F. S. Farmer. 1974. Adenosine phosphates in germinating radish (*Raphanus sativus* L.) seeds. Plant Physiol. 54:560-563.

4. Hanson, W. D., D. E. Moreland, and C. R. Shriner. 1975. Correlation of mitochondrial activities and plant vigor with genetic background. (Accepted by Crop Science)

5. Alsop, W. R., and D. E. Moreland. Effects of herbicides on the light-activated, magnesium-dependent ATPase of isolated spinach (*Spinacia oleracea* L.) chloroplasts. (Accepted by Pestic. Biochem. Physiol.)

6. Tomlinson, Jr., P. F., and D. E. Moreland. Cyanide-resistant respiration of sweet potato mitochondria. (Accepted by Plant Physiol.)

7. Moreland, D. E., and J. L. Hilton. Chapter 17 - Actions on photosynthetic systems. For the 2nd edition of Physiology and Biochemistry of Herbicides, L. J. Audus, ed., Academic Press, London. (Accepted by editor)

8. Hammerschlag, R. S., J. L. Hilton, P. G. Bartels, and D. E. Moreland. Contribution of side chains to karbutilate mode of action. (Submitted to Weed Sci.)

NATIONAL PROGRAM STAFF

Format for Providing Information for
ARS Photosynthesis Workshop

Prepared by W. L. Ogren Date November 1, 1974

(No more than 2 pages)

1. Number and Title of Work Reporting Unit (WRU) 501-3311-10610 Soybean Production Practices
2. Location(s) Urbana, Illinois
3. Scientist's Name, Address, and Telephone Number See attached sheet
4. Current SMYs Working on Photosynthesis at Your Location Three (3).
5. Percent of Your Time Spent on Photosynthesis Research 100%
6. Net Budget--(1) Salaries $33,700 (2) Operations $14,000
7. Mission of Research Increase soybean yields
8. Objectives of Research Increase photosynthetic productivity in soybeans.
9. Status of Present Research See attached sheet.
10. Significant Research Accomplishments (Be specific and brief) Discovered oxygen sensitivity of RuDP carboxylase.
11. Impact of Research on Science and General Public See attached sheet
12. Obstacles to Achieving Objectives Not yet determined.
13. Future Lines of Research for Emphasis See attached sheet.
14. Research, Facilities, and Personnel Needs Post-doctoral position to provide assistance in biochemical technology.
15. Extent of Cooperation--Names of Persons and Institutions R. H. Hageman and J. M. Widholm, University of Illinois, Urbana, IL.
16. Titles and Places of Publications in the Past Two Years See attached sheet
17. Other Considerations None
18. Recommendations None

3. William L. Ogren
U. S. Regional Soybean Laboratory
160 Davenport Hall
Urbana, IL 61801
217-344-0622

9. Have identified site of potential major increase in photosynthetic productivity. Problem now is to advantageously manipulate this site.

11. Science - Greatly stimulated research on what is probably the most important regulatory enzyme (RuDP carboxylase) of C_3 photosynthesis and photorespiration.

    General public - none.

13. Alteration of RuDP carboxylase so that oxygen-sensitivity of photosynthesis (O_2 inhibition of photosynthesis and stimulation of photorespiration) is reduced.

16. Laing, W. A., W. L. Ogren and R. H. Hageman. 1974. Regulation of soybean net photosynthetic CO_2 fixation by the interaction of CO_2, O_2, and ribulose 1,5-diphosphate carboxylase. Plant Physiol., in press (November).

    Singh, M., W. L. Ogren, and J. M. Widholm, 1974. Photosynthetic characteristics of several C_3 and C_4 plant species grown under different light intensities. Crop Sci. 14:563-566.

    Ogren, W. L., and R. W. Rinne. 1973. Photosynthesis and seed metabolism. In: B. E. Caldwell, ed., Soybeans: Improvement, Production, and Uses. American Society of Agronomy, Madison.

    Chollet, R., and W. L. Ogren. 1973. Photosynthetic carbon metabolism in isolated maize bundle sheath strands. Plant Physiol. 51:787-792.

Prepared by James E. Pallas, Jr. Date 10-30-74

1. WRU NUMBER: 501-7903-12330
   Title: Soil-Plant-Atmosphere Interaction Affecting Use of Solar Energy and Water in the South
2. Southern Piedmont Conservation Research Center, Watkinsville, Ga.
3. James. E. Pallas, Jr., Box 555, Watkinsville, Ga. 30677
4. 1.5
5. 75%
6. Salaries $31,398 Operation $6,750
7. To understand the soil-plant-stmosphere continuum so as to allow intelligent management of the system as well as prediction of output for given input. Specifically to achieve increased photosynthetic and water use efficiency especially under southeastern cropping is the primary mission of this research activity.
8. 1. To more fully understand the interaction of environmental change on the photosynthetic rate of certain cropped species.
   2. To characterize selected germ plasm of several important species cropped in the southeast as to its photosynthetic reactivity and potential as primarily tested under controlled environmental conditions (presently tomatoes and peanuts).
   3. To measure and study certain parameters concerning this photosynthetic reactivity and potential i.e. diffusional resistances, especially stomatal.
   4. To concentrate on studies in stomatal activity (e.g. anatomy, morphology, physiology and biochemistry) in order to more fully understand the stomate as an attenuator in the plants photosynthetic scheme.
9. Experimentation is underway to assess the endogenous counterpart of photosynthesis of Arachis hypogaea as well as the interaction of soil-plant water availability with photosynthetic potential.
10. Identification of an endogenous circadian control mechanism of photosynthesis and related processes in Arachis hypogaea as well as a light response with the same species more indicative of C_4 metabolism. Further illucidation of stomatal mechanism has indicated some enzymatic aspects are similar to CAM metabolism but are definitely associated with a K+ pump.
11. These findings are quite basic and are published in reputable journals. Impact on general public depends on news coverage.
12. Lack of physical facilities, technical help and supportive monies.
13. Continuation of studies on water relations and photosynthetic potential of land plants.
14. Need to return to research in biochemistry of stomatal mechanism as well as study the circadian timing mechanism; both appear interrelated. Urgent need for growth chamber facilities and updating of lab equipment. Recapture of chemical aids, one or better yet both the chemical technitians originally associated with the project.
15. Co-workers (as validated in item 16) 1. Dr. C. C. Black, University of Georgia, Athens, Ga. 2. Dr. R. A. Dilley, Purdue University, Lafayette, Indiana. 3. Ms. Patricia Jackson, USDA, Beltsville, Maryland. 4. Dr. Joseph Mendicino, University of Georgia. 5. Dr. B. Michel, University of Georgia, Athens, Ga. 6. Dr. H. Mollenhauer/USDA, College Station, TX.

7. Dr. Y. B. Samish, Tel-Aviv University, Tel-Aviv, Israel. 8. Dr. C. M. Wilmer, University of Sterling, Sterling, Scotland.

16. 1. Transpiration of _Antirrhinum majus_ L. 'Panama' as influenced by soil temperature. J. Amer. Soc. Hort. Sci. 97(1):34-37.

2. Electron microscopic evidence for plasmodesmata in dicotyledonous guard cells. Science 175:1275.

3. Photophosphorylation can provide sufficient adenosine 5'-triphosphate to drive K+ movements during stomatal opening. Plant Physiol. 49(4):649-650.

4. A re-evaluation of soybean leaf photorespiration. Plant Physiol 50-28.

5. The hydrolysis of maltodextrins by a β-amylase isolated from leaves of _Vicia faba_. Biochim. Biophys. Acta 276:491-507.

6. Physiological implications of _Vicia faba_ and _Nicotiana tabaccum_ guard-cell ultrastructure. Amer. J. Bot. 59(5):504-514.

7. A survey of stomatal movements and associated potassium fluxes in the plant kingdom. Can. J. Bot. 51(1):37-42.

8. Detection of high levels of phosphoenolpyruvate carboxylase in leaf epidermal tissue and its significance in stomatal movements. Life Sciences 12(II):151-155.

9. Diurnal changes in transpiration and daily photosynthetic rate of several crop plants. Crop Sci. 13:82-84.

10. Organic Acid Changes in the epidermis of _Vicia faba_ and their implication in stomatal movement. Plant Physiol 51:588

11. Carbon Dioxide metabolism in leaf epidermal tissue. Plant Physiol. 52:448.

12. A semiclosed compensating system for the control of CO_2 and water vapor concentrations and the calculation of their exchange rates. Photosynthetica 7(4):345-350.

13. Irrigation can pay a bonus with better seed quality. Southeastern Peanut Farmer. April 1973.

14. Photosynthetic response of peanut. Crop Science 14:478-482.

15. Endogenous rhythmic activity of photosynthesis, transpiration, dark respiration, and carbon dioxide compensation point of peanut leaves. Plant Physiol 53:907:911.

16. Stomatal movements and ion fluxes within epidermis of _Commelina communis_. Nature (in press)

17. Major element composition of epidermal and mesophyll tissue of Commelina communis L. and Vicia Faba L.: Some further considerations of the role of ions in stomatal functioning. J. of Experimental Botany 25(88)

Information for
ARS Photosynthesis Workshop

Prepared by: Doyle B. Peters   Date: October 30, 1974

1. Number and Title of Work Reporting Unit (WRU): 3311-12330-001 Transport of Mass, Momentum and Energy in Soil-Plant-Atmosphere Systems.

2. Location: Urbana, Illinois.

3. Scientist's Name, Address, and Telephone Number: Doyle B. Peters, S-212 Turner Hall, Urbana, Illinois 61801. Ph: (Commercial) 217-333-4370, (FTS) 217-356-1135.

4. Current SMYs Working on Photosynthesis at This Location: One.

5. Percent of Time Spent on Photosynthesis Research: 60%.

6. Net Budget: (1) Salaries $125,000   (2) Operations $39,000

7. Mission of Research: To determine the photosynthetic rates in natural field situations and assess the environmental, genetic, and cultural effects on photosynthesis.

8. Objectives of Research:
   (1) Correlate soybean night leaf temperatures with cloudiness, wind, and stomatal opening.

   (2) Compare cell wall water status with overall leaf water status by means of refractive index measurements on the cell walls.

   (3) Determine the respiration, evaporation, and photosynthesis rates of a number of wheat, alfalfa, and soybean varieties in a field situation.

   (4) Determine the amount of atmospheric nitrogen fixed by soybean rhizobium and determine the fate of fixed and mineral nitrogen absorbed by soybeans.

   (5) Determine the effect of irrigation frequency on the yield of a number of vegetable and agronomic crops in the humid region.

9. Status of Present Research: Ongoing research as listed in item 8 above.

10. Significant Research Accomplishments:
    (1) Determined that nighttime temperature is dominant yield determinant.

    (2) Developed technique for field situation measurement of photosynthesis, respiration, and evaporation.

    (3) Have complete season record of photosynthesis and dark respiration of 16 soybean varieties.

11. Impact of Research on Science and General Public: Not known.

12. Obstacles to Achieving Objectives: Lack of sufficient personnel to carry out adequately all ongoing projects. Location has gone from six SMYs to two SMYs.

13. Future Lines of Research for Emphasis:
(1) Emphasize studies on nitrogen-carbon balance requirements.

(2) More work on symbiotic fixation as related to photosynthesis.

(3) Assess energy requirements of plant roots.

(4) More detailed studies on photosynthesis and dark respiration with genetic and management variables.

14. Research, Facilities, and Personnel Needs:
(1) Facilities are adequate, though crowded.

(2) Additional professional staff is needed.

15. Extent of Cooperation--Names of Persons and Institutions:
(1) USDA: James E. Harper
William L. Ogren
Robert W. Rinne
Richard L. Cooper

(2) University of Illinois: Richard R. Johnson
Charles W. Boast
Richard H. Hageman

16. Titles and Places of Publications in Past Two Years:

Purvis, A. C., D. B. Peters and R. H. Hageman. 1974. Effect of carbon dioxide on nitrate accumulation and nitrate reductase induction in corn seedlings. Plant Physiol. 53:934-941.

Peters, D. B., B. F. Clough, R. A. Garves and G. R. Stahl. 1974. Measurement of dark respiration, evaporation, and photosynthesis in field plots. Agron. J. 66:460-462.

Mederski, H. J., D. L. Jeffers and D. B. Peters. 1973. Water and water relations. In Soybeans: Improvement, Production, and Uses, Agron. Monograph #16 (ed. B. E. Caldwell), Am. Soc. Agron., pp. 239-266.

Luxmoore, R. J., R. J. Millington and D. B. Peters. 1973. Row-crop microclimate. In Plant Response to Climatic Factors, Proc. Uppsala Symposium (UNESCO), 1970, pp. 377-388.

Aston, A. R., R. J. Millington and D. B. Peters. 1973. The energy balance of leaves. In Plant Response to Climatic Factors, Proc. Uppsala Symposium (UNESCO), 1970, pp. 37-44.

Attach.-CRIS report dated 4/25/74

Information for ARS Photosynthesis Workshop

Prepared by John R. Potter Date October 11, 1974

1. WRU 7402-12070-001 Physiology of weeds and herbicide action
   WRU 7402-12070-003 Influence of environment on weed growth and physiology

2. Southern Weed Science Laboratory, Stoneville, MS

3. John R. Potter, Southern Weed Science Laboratory, P.O. Box 225, Stoneville, Mississippi 38776; Tele.: (601) 686-2311, Ext. 214

4. Unknown

5. I spend about 90% of my time on photosynthesis-related research.

6. Net budget--(1) Salaries $30,000 (2) Operations $15,000

7. Mission: Determine how environmental variables affect life processes in weeds.

8. Objectives: (a) Correlate growth with carbon dioxide exchange rates so that growth can be predicted from photosynthesis and respiration data; (b) determine effect of temperature and other environmental variables on dry weight accumulation, photosynthesis and respiration; (c) determine the effect of light temperature on the action of bentazon and fluometuron (photosynthesis inhibiting herbicides); and (d) determine the sequence of biochemical changes during the onset of photosynthetic competence in seedlings that have recently germinated.

9. The status of the above items is as follows: (a and b) The data are just now to the point where I can make some conclusions. I have dry weight and leaf area data for 6 weed and 3 crop species grown under 3 temperature regimens in growth chambers. I have complete photosynthesis and respiration data for 1 temperature regimen. (c) Two manuscripts have been prepared (one in press and one presently at NTE). See item 10 (c). (d) The data for one species (velvetleaf) are complete enough to prepare a manuscript. See item 10 (d).

10. (a) Growth rates of weed species (velvetleaf, spurred anoda, prickly sida, cocklebur, johnsongrass and pigweed) generally are as rapid or more rapid than growth rates of cotton, corn, or soybean. (b) Rates of dry weight accumulation correlate well with growth rates predicted from photosynthesis and respiration data. (c) The action of bentazon is strongly light dependent. Fluometuron not only inhibits photosynthesis, but it has a direct effect on the synthesis of chloroplast membranes. (d) The development of photosynthetic competence in velvetleaf occurs as soon as the cotyledons emerge at 3 days. At this time, the cotyledons are only pale green, and the chloroplasts contain only rudimentary grana. As the chloroplasts mature, the rate of photosynthesis increases rapidly until it reaches a maximum that exceeds that of mature leaves by 30%.

11. The modeling effort should allow one to predict the relative competitiveness of weeds under a wide variety of environmental conditions. The weed

data are useful to modeling crop growth in that weeds serve as a sink for nutrients. This combination of information should lead to management recommendations to producers who are concerned about weed infestations. The herbicide studies help explain the action of these chemicals and should aid in their more effective use. The biochemical studies on recently germinated seedlings provide a basis for comparing differences in physiology. Identification of differences could lead to discovery of novel control methods.

12. There are no technical or physical obstacles, but the volume of data in the modeling effort requires considerable time to analyze.

13. For the near future, I will be imposing different species and environmental variables on my existing systems.

14. I am now at the point where I could supervise the work of graduate students or a post-doctoral associate. Help of this caliber would greatly facilitate my program.

15. I am presently involved in the modeling effort by ARS-Mississippi State University at Starkville, MS. I have been consulting with John Hesketh (ARS) at the Boll Weevil Lab for the past year.

16. Boyer, J.S. and Potter, J.R. Chloroplast response to low leaf water potentials. I. Role of turgor. Plant Physiol. 51:989-992. 1973

Potter, J.R. and Boyer, J.S. Chloroplast response to low leaf water potentials. Role of osmotic potentials. Plant Physiol. 51:993-997. 1973.

Wergin, W.P. and Potter, J.R. The ultrastructural and physiological effects of bentazon on leaves of cocklebur. Weed Sci. Soc. Amer., pp 125-126 (Abs.) 1974.

Potter, J.R. and Wergin, W.P. Effects of fluometuron on photosynthesis, respiration and ultrastructure of developing velvetleaf seedlings. Plant Physiol. Annual Supplement, p 5, No. 24 (Abs.). June 1974.

Wergin, W.P. and Potter, J.R. The effects of fluometuron on the ultrastructural development, chlorophyll accumulation and photosynthetic competence in developing velvetleaf seedlings. Pesticide Biochemistry and Physiology, In press.

Potter, J.R. and Wergin, W.P. The role of light in bentazon toxicity to cocklebur: Physiology and Ultrastructure. Manuscript now at NTE. To be submitted to Pesticide Biochemistry and Physiology.

17. None

18. None

NATIONAL PROGRAM STAFF

Information for ARS Photosynthesis Workshop

Prepared by Bonnie J. Reger   Date 10/30/74

1. Number and Title of Work Reporting Unit (WRU):

   7402-12070   Weed Biology and Mechansim of Control

2. Location:

   Southern Weed Science Laboratory
   Stoneville, Mississippi 38776

3. Scientist's Name, Address, and Telephone Number:

   Dr. Bonnie J. Reger
   Southern Weed Science Laboratory
   Stoneville, Mississippi 38776
   601-686-2311 Ext. 215 Commercial
   601-686-1110 FTS

4. Current SMYs Working on Photosynthesis at your Location:

   0.5

5. Percent of Your Time Spent on Photosynthesis Research:

   Approximately 60% of my time will be spent on photosynthesis.

6. Net Budget--(1) Salaries $21,000 (2) Operations $8,000

7. Mission of Research:

   To develop new principles of weed control practices based on information obtained from comparative physiological and biochemical studies of crop plants and their respective hard-to-kill weeds.

8. Objectives of Research:

   To determine physiological or biochemical differences between crops and weeds--photosynthetic carbon metabolism including photorespiration, translocation, and biochemical requirements for seed germination and seedling establishment.

9. Status of Present Research:

   My present ARS research has been concerned with seed dormancy and germination; however, I intend to initiate work in photosynthesis shortly.

10. Significant Research Accomplishments:

(1) Photosynthesis - graduate program research

Corrected contradictory reports regarding negative Emerson enhancement--showed enhancement even when the chlorophyll a/b ratio was 6 rather than the normal 3. (Plant Physiol. 1970. 46:568-575.)

(2) Postdoc work - two labs at Oak Ridge National Laboratory

My most significant accomplishments were: identifying and purifying cytoplasmic and chloroplastic aminoacyl-tRNA synthetases, demonstrating the specificity of each enzyme (chloroplast enzymes recognized only chloroplast tRNAs and cytoplasmic enzymes recognized only cytoplasmic tRNAs), and obtaining the first information indicating a chloroplast aminoacyl-tRNA synthetase was coded for by nuclear genes and translated on cytoplasmic ribosomes. (Proc. Nat'l. Acad. Sci. 1970. 67:1207-1213.)

(3) ARS work - Stoneville

Seed germination: Polysome formation was described for common purslane seeds, which display light-controlled dormancy. While a low level of polysomes do form on imbibition, light stimulates polysome formation. The light-stimulated polysomes preceed radicle protrusion but must be related to radicle elongation since six hours of light are required in order to see a significant increase in polysomes. Prerequisites to the light-stimulated polysomes and their products are under present investigation.

11. Impact of Research on Science and General Public:

While the above accomplishments have contributed to science they have had no impact on the general public.

12. Obstacles to Achieving Objectives:

None

13. Future Lines of Research for Emphasis:

Initiation of work in photosynthesis:

Present information regarding the C_3/C_4 classification of plants will be used in an attempt to establish the feasibility of new herbicides based on selective inhibition of enzymes unique to either C_3 or C_4 weed species. Inhibitors of PEP carboxylase and pyruvate P. dikinase will be sought in the case of C_4 weeds. Inhibitors of glycolate oxidase and other peroxisomal enzymes will be sought in the case of C_3 weeds.

Although most weeds are C_4 plants, there are some C_3 species and these appear to be very competitive. Weed species which appear to be exceptional C_3 plants will be investigated to determine physiological or biochemical factors which contribute to their competitive nature.

14. Research, Facilities, and Personnel Needs:

While we appear to be adequately supported we could use additional professional slots, support personnel (including a draftsman), and a postdoctoral program.

15. Extent of Cooperation--Names of Persons and Institutions:

None established in photosynthesis yet.

16. Titles and Places of Publications in the Past Two Years:

Papers:

Reger, B. J., G. H. Egley, and C. R. Swanson. (1975). Polysome formation in common purslane seeds. Plant Physiol. In Press.

Abstracts:

Smith, E. W., Bonnie J. Reger, and G. H. Egley. 1973. Enzyme activities during development and germination of weed seeds. Proc. Assoc. Southern Agricultural Workers, Inc. 70:205-206.

Egley, G. H. and B. J. Reger. 1973. Dormancy and germination of weed seeds. Proc. Assoc. Southern Agricultural Workers, Inc. 70:205.

Reger, Bonnie J., G. H. Egley, C. R. Swanson, and E. W. Smith. 1974. Polysome formation in relation to seed dormancy of common purslane, prickly sida, and redroot pigweed. Proc. South. Weed Sci. Soc., p. 356.

Reger, Bonnie J., C. R. Swanson, G. H. Egley, and E. W. Smith. 1974. Induction of polysomes and isocitratase in common purslane seeds prior to germination. Southern Section of the Amer. Soc. of Plant Physiologists, Memphis, TN. (unpublished)

Reger, Bonnie J., G. H. Egley, and C. R. Swanson. 1974. Light-stimulation of polysome formation in common purslane seeds. Weed Sci. Soc. Amer., pp. 86-87.

Egley, G. H. and B. J. Reger. 1974. Seed-coverings and prickly sida seed dormancy. Weed Sci. Soc. Amer., p. 24.

17. Other Considerations:

None

18. Recommendations:

None

Prepared by Dr. R. W. Rinne   October 29, 1974

1. Number and Title of Work Reporting Unit
   WRU 501-3311-10610, Soybean Production Practices
2. Location
   Urbana, Illinois
3. Scientist's Name, Address, and Telephone Number
   Dr. R. W. Rinne   Comm. 217-344-0622
   160 Davenport Hall   FTS   217-356-1124
   University of Illinois
   Urbana, Illinois 61801
4. Current SMYs Working on Photosynthesis at Your Location
   Four
5. Percent of Your Time Spent on Photosynthesis
   100% of my time is spent on how the soybean converts the sucrose from photosynthesis into protein and oil.
6. Net Budget
   (1) Salaries $38,000
   (2) Operations $14,000
7. Mission of Research
   To improve the quanity and quality of the protein and oil which make up to 40 to 20% respectively of the dry weight of a mature soybean.
8. Objections of Research
   To more precisely determine the metabolic pathway of carbon subsequent to glycolysis in the developing soybean seed with special emphasis on protein and oil production. To determine what controls protein and oil production.
9. Status of Present Research
   Finishing up a study which is centered around following acetate, pyruvate and glucose metabolism in the developing soybean seed.
   Investigating the role and importance of phospholipids in triglyceride (oil) biosynthesis. Investigating the role of the enzyme citrate lyase in relationship to its ability to furnish acetate moisture needed for triglyceride (oil) biosynthesis.
10. Significant Research Accomplishments
    Identified N-acylphosphatidylethanolamine to be a major phospholipid in developing soybean seeds. This new complex phospholipid would appear to play an important role in triglyceride (oil) biosynthesis. Citrate lyase has been shown for the first time to be present in plant. This enzyme has been shown to be very important in animal systems with respect to fat (oil) synthesis.
11. Impact of Research on Science and General Public
    The impact from this research would be to eventually control protein and oil synthesis in soybeans. To have soybean varieties with high protein and to have soybean varieties with high oil.
12. Obstacles to Achieving Objectives
    Lack of knowledge in the area of metabolism of developing seeds.
13. Future Line of Research for Emphasis
    To determine the involvement of organelles in the production of precursors for protein and oil synthesis and to study the production of high-energy phosphoytatel compounds which are necessary to the synthetic reactions and which may act as controlling mechanisms.
14. Research, Facilities, and Personnel Needs
    Definitely could use more funding, space and technical assistance. Lack of space is definitely a factor.
15. Extent of Cooperation--Names of Persons and Institutions
    Physiologist at University of Illinois, both state and federal.
    Dr. C. A. Brim, ARS, Soybean Breeding, North Carolina State.

Titles and Places of Publication in the Past Two Years

The Plant Geneticist's Contribution Toward Changing Lipid and Amino Acid Composition of Soybeans. J. Am. Oil Chem. Soc. 1972.

Protein, Oil and Fatty Acids in Developing Soybean Seeds. Crop Sci. 1972.

Photosynthesis and Seed Metabolism. _In_: Soybeans: Improvement, Production, and Uses. 1973.

Phospholipids in the Developing Soybean Seed. Plant Physiology, 1974.

Citrate Cleavage Enzyme from Developing Soybean Cotyledons. Plant Physiology. 1974.

Other Considerations

None

Recommendations

More research is needed on the developing seeds. An area which very few scientists work in.

1) WRU: 12330; Microclimatology

2) Location: Ithaca, New York

3) T. R. Sinclair and E. R. Lemon
Agronomy Department
Bradfield Hall
Cornell University
Ithaca, New York 14853

Commercial Phone: 607-256-4573
FTS Phone: 607-272-4573

4) SMYs on Photosynthesis: 1

5) Sinclair's time on photosynthesis: 2/3

6) Salaries: $93,700 + $15,900 on cooperative agreement

Operations: $10,200

7&8) Objective: To measure, model, understand, and control the plant, soil, water, and meteorological factors involved in the exchange of radiant energy, the aerodynamic transport of atmospheric constituents, and the removal of atmospheric pollutants.

9) Status: The final reports on a number of years of intensive research on the micrometeorological processes within crops are being prepared. The emphasis of the project will be shifted from studies of the physical processes influencing crop gas exchange to more intense physiological investigations. Research will be undertaken on the dynamics of the transpiration and photosynthesis of individual leaves under field conditions.

10) Significance: The microenvironment of several crops has been well documented. The micrometeorological processes which interact with the plant canopy to influence crop CO_2 assimilation and transpiration have been elucidated. The culmination of these studies has been the development of a soil-plant-atmosphere model (SPAM) which simulates the physical interaction of crops and their environment. SPAM has been found quite adequate for describing the micrometeorological limitations to crop gas exchange.

11) Impact: This research has provided data and a tool for understanding and simulating the microenvironment of vegetative canopies. The influence of micrometeorological processes on crop photosynthesis, crop water loss, environmental controls of crop development, and the growth of pests (weeds and diseases) within a crop are now known to a great extent.

12) Obstacles: The physiological controls on gaseous exchange between the atmosphere and crops have been found to be of very considerable importance. Therefore, a great deal of information is yet required on the dynamic characteristics of these physiological processes to model and control the loss of water and uptake of CO_2 and pollutants by crops.

13) Future: Future research will be designed to study the hypothesis that crops can be genotypically manipulated to improve their water-use efficiency. Therefore, physiological techniques for both limiting crop water loss and improving CO_2 assimilation will be studied. Since the species on which most of the project's work will be concentrated is soybeans, methods for improving seed yield through increased nitrogen availability in the plant will be studied. It is envisaged that studies on the interaction of CO_2 assimilation and N_2 fixation will be undertaken.

14) Needs: The greatest need of the project is additional support for purchase of material and capital equipment. Expenditures are required to improve and modernize the project's data acquisition system and the system used to measure plant gas exchange. Additional funds are required to support developmental costs for constructing the system to be used to monitor the exchange of various gases by the soybean plants. Of course, to fulfill the potential of the project the two personnel positions now vacant (Systems Analyst and Secretary) must be filled.

15) Cooperation:

a) A two-year project to elucidate the microenvironment of vineyards and potential environmental affects on yield of grapes is now being completed. Cooperator: Dr. Nelson Shaulis, Department of Pomology and Viticulture, New York Agricultural Experiment Station, Geneva, N.Y.

b) The project has participated in a continuing study of the volitization and diffusion of pesticides from field crops. Cooperator: Dr. Allan Taylor, USDA-ARS, Agricultural Chemicals Management Laboratory, Beltsville, MD.

16) Publications:

<u>FY 1973</u>

Allen, L. H. Jr. (1973). Crop micrometeorology: A. Wide-row light penetration. B. Carbon dioxide enrichment and diffusion. Ph.D. Thesis, Cornell University, 366 pp.

Allen, L. H. Jr. and E. R. Lemon. (1972). Net radiation frequency distribution in a corn crop. Boundary-Layer Meteorol. 3:246-254.

Allen, L. H. Jr., Edgar Lemon, and Ludwig Muller. (1972). Environment of a Costa Rican forest. Ecology 53:102-111.

Bingham, G. E., M. N. Johnson and E. R. Lemon. (1972). Influence of heat sink design on thermocouple psychrometer response. In: Psychrometry in water relations research. Ed: R. W. Brown and B. P. Van Haveren. Utah Agr. Res. Stat.

Desjardins, R. L. (1972). A study of carbon dioxide and sensible heat fluxes using the eddy correlation technique. Ph.D. Thesis, Cornell University. 174 pp.

Lemon. E. R., D. W. Stewart, R. W. Shawcroft, and S. E. Jensen. (1973). Experiments in predicting evapotranspiration by simulation with a soil-plant-atmosphere model (SPAM). In: Field Soil Water Regime. Ed. R. Russel Bruce. Soil Science Society of America Special Publication, Madison, Wisconsin.

Shawcroft, R. W., and E. R. Lemon. (1972). Estimate of internal crop water status from meteorological and plant parameters. In: Plant Responses to Climatic Factors - Proceedings of Uppsala Symposium, UNESCO. pp. 449-459. (Ecology in Conservation - V).

FY 1974

L. H. Allen, Jr., R. J. Hanks, J. K. Aase, and H. R. Gardner. Carbon dioxide uptake by wide-row grain sorghum computed by the profile Bowen ratio. Agronomy Journal Vol. 66, Jan.--Feb. 1974, p. 35-41.

L. H. Allen, Jr. Model of light penetration into a wide-row crop. Agronomy Journal Vol. 66, Jan.--Feb. 1974, p 41-47.

E. R. Lemon. Predicting crop climate and net carbon dioxide exchange. Photosynthetica Vol. 7, p. 408-413. (1973).

E. R. Lemon, D. W. Stewart, R. W. Shawcroft, and S. E. Jensen. Experiments in predicting evapotranspiration by simulation with a soil-plant-atmosphere-model (SPAM). In: R. R. Bruce (ed.): Field Soil Water Regime. Soil Sci. Soc. Amer. Spec. Pub. Madison, Wisc. p 57-76. (1973).

E. R. Lemon. Critique of "High-efficiency photosynthesis"--
Olle Bjorkman and Joseph Berry. (Scientific American Oct. 1973) Scientific American, Jan. 1974.

R. L. Desjardins, T. R. Sinclair, and E. R. Lemon. Light fluctuations in corn. Agronomy Journal, Vol. 65, p. 904-908. (1973).

R. L. Desjardins and E. R. Lemon. Limitations of an eddy-correlations technique for the determination of the carbon dioxide sensible heat fluxes. Boundary-Layer Meteorology Vol. 5, p. 475-488. (1974).

T. R. Sinclair and E. R. Lemon. Penetration of photosynthetically active radiation in corn canopies. Agronomy Journal, Vol. 66 p. 201-205. (1974).

T. R. Sinclair, R. L. Desjardins, and E. R. Lemon. Analysis of sampling errors with traversing radiation sensors in corn canopies." Agronomy Journal, Vol. 66, p. 214-217. (1974).

R. E. Smart and G. E. Bingham. Rapid estimates of relative water content. Plant Physiology, Vol. 53; p. 258-260.

INFORMATION FOR ARS PHOTOSYNTHESIS WORKSHOP

Prepared by Freeman W. Snyder

October 1974

1. 501-3508-10710-003 Physiology of sugarbeet in the Great Lakes region. Formerly under WRU 401-3309-10710-001.

2. East Lansing, Michigan

3. Freeman W. Snyder, ARS, USDA, P. O. Box 1633, East Lansing, MI 48823 Phone 517-355-7456

4. 0.7 SMY - indirectly deals with photosynthetic efficiency

5. 0.7 SMY

6. Net Budget - (1) Salaries 20,000 (2) Operations 8,500

7. Mission: Increase root and sucrose yield of sugarbeet

8. Objectives: Use growth analysis techniques to isolate individual plants within sugarbeet breeding lines that (1) accrete leaf area most rapidly and simultaneously (2) partition a greater portion of their photosynthate into the taproot. (3) Select and use these plants in breeding higher yielding sugarbeets.

9. Status: (1) Currently determining whether selecting seedlings for extremes in leaf area is effective. (2) Comparing hybrids and their breeding components for leaf-blade weight and taproot-hypocotyl weight 22 days after emergence in the growth chamber with root yield of hybrids in full-season field experiments.

10. Accomplishments: (1) In sugarbeet seedlings 22 days after emergence, leaf area correlates with fresh weight of leaf blades, r = about 0.95**, hence leaf weight can be substituted for time consuming leaf area measurements in many cases. (2) Selection pressure is effective in altering the proportion of taproot-hypocotyl weight to leaf-blade weight in sugarbeet seedlings 22 days after emergence, which is taken as presumptive evidence that selection pressure effectively alters the growth partitioning ratio (GPR) for taproot. (3) Have some evidence that the differential between low and high GPR selections is maintained at least to 70 days after planting in the field. (4) Compared leaf area and dry matter accumulation by maize and sugarbeet under identical conditions of growth. See reference in item 16 and enclosed reprint. (5) Determined effect of CO_2 concentration on glycine and serine formation during photorespiration. See reference item 16 and enclosed reprint.

11. Impact: Too early to evaluate impact.

12. Obstacles: (1) Lack of slot for a full-time technician. (2) Limited growth-chamber capacity to grow and select plants for further study.

13. Research is needed to determine what mechanisms within the plants cause the marked differences in the GPR of various selections, however, I do not have equipment and facilities at this time to do such research.

14. Needs: (1) Full-time technician. (2) Additional growth chambers.

15. Gerald E. Coe, ARS, USDA, Beltsville, MD
George J. Hogaboam, ARS, USDA, East Lansing, MI
Richard C. Zielke, Farmers and Manufacturers Beet Sugar Assoc., Saginaw, MI

16. Snyder, F. W. and N. E. Tolbert. 1974. Effect of CO_2 concentration on glycine and serine formation during photorespiration. Plant Physiol. 53: 514-515.

Snyder, F. W. 1974. Comparative leaf area and dry matter accumulation by maize and sugarbeet. Crop Sci. 14: 529-533.

17. - - - -

18. Recommendations: Since leaf area plays such a vital role in trapping solar radiation, and in many crop plants considerable time elapses between planting and canopy coverage of the land surface, accelerating leaf accretion could increase yield, especially for indeterminate species. Individual plants of sugarbeet breeding lines may differ up to 10-fold (2- to 3-fold is common) 22 days after emergence in growth chambers. The magnitude of these differences cannot be attributed to environmental variation. I recommend that research into the internal mechanisms regulating leaf accretion be initiated, since such research could provide knowledge for accelerating leaf accretion.

ARS PHOTOSYNTHESIS WORKSHOP

Prepared by C. Y. Sullivan, November 14, 1974

1. WRU number: 3705-10530, Physiology of grain sorghum

2. Location: University of Nebraska
   Department of Agronomy
   Lincoln, Nebraska

3. Charles Y. Sullivan, ARS, USDA. Phone (402) 472-3058

4. Current SMYs Working on Photosynthesis: .5

5. Percent of My Time Spent on Photosynthesis: 20

6. Net Budget: Salaries $22,750 Operational $3,000

7. Mission of Research: Agricultural Production Efficiency

8. Objectives of Research: (1) Define limiting physiological factors involved in optimum grain sorghum production and where appropriate to compare these to stress responses in different genotypes; (2) to determine the biochemical and physiological effects of stress on photosynthesis, and other metabolic and growth processes; (3) to evaluate the effects of prolonged or short-time exposure to environmental extremes on photosynthesis and other metabolic processes; (4) determine the stage of development at which stress most effects processes such as photosynthesis; (5) to develop techniques suitable for screening germplasm for use in sorghum breeding improvement.

9. Status of Present Research: A great deal of background information has been obtained toward the above objectives. Differences in photosynthetic responses to drought and heat stress have been shown for different genotypes, when evaluated by isolated chloroplasts and intact leaves. A number of sorghum genotypes have been screened for true desiccation and heat tolerance by a previously developed leaf disc technique and the results, in some cases, compared to photosynthetic responses. It is indicated that the leaf disc test can be used as a rough screening for tolerance of the photosynthetic apparatus to heat and desiccation stress. Relations between stomatal response, leaf and soil water potential, and temperature and stress effects on the photochemical apparatus are being studied with different genotypes. Studies have shown that plants differ in their abilities to acclimate to their environment, including effects on photosynthesis. An evaluation is being made in the stress responses of sorghum and corn.

10. Significant Research Accomplishments: Developed a practical, simple method for measuring desiccation and heat tolerance of plant tissue. Determined some physiological bases for differences in heat tolerance of sorghum, corn and

pearl millet. Found influence of drought cycles on sorghum stomatal response. The importance of natural stress hardening and other responses to previous environmental conditions in plant response has been elucidated.

11. Impact of Research on Science and General Public: Basic information gained toward understanding plant responses to their environment and application of results in a plant breeding program.

12. Obstacles to Achieving Objectives. Inadequate operating funds and technical assistance.

13. Future Line of Research for Emphasis: Screening random mating populations for stress resistance in cooperation with a breeder-geneticist. Screening for photosynthetic efficiency. Further determination of the physical and chemical aspects of stress on photosynthesis.

14. Research, Facilities and Personnel Needs: Well designed and constructed greenhouses and headhouse needed. There is a critical need for an ARS technician assigned to physiology. Presently sharing technician with the geneticist which does not lend well to continuity of physiological research.

15. Cooperation: Dr. J. D. Eastin, Dr. M. D. Clegg, Dr. J. W. Maranville, Plant Physiologist; Dr. W. M. Ross, Geneticist; Dr. L. Dunkle, Pathologist; Dr. J. H. Williams, Soybean Breeder; Dr. W. A. Compton, Corn Breeder-Geneticists, University of Nebraska; Dr. Abram Blum, Breeder-Physiologist, Volcani Center, Bet-Dagan, Israel; Dr. P. M. Saint-Clair, Plant Physiologist, Laval University, Quebec, Canada; Dr. Hugh Doggett, ICRASAT, Hyderabad, India.

16. Publications 1973-74. Blum, A., C. Y. Sullivan, and J. D. Eastin. 1973. On the pressure chamber technique for estimating leaf water potential in sorghum. Agron. J. 63:337-338.
Eastin, J. D., J. H. Hultquist, and C. Y. Sullivan. 1973. Physiologic maturity in grain sorghum. Crop Sci. 13:175-177.
Eastin, J. D. and C. Y. Sullivan. 1973. Yield considerations in selected cereals. In Mechanisms of Regulation of Plant Growth. Proc. of Int. Plant Physiol. Symp., Palmerston North, New Zealand (in press).
Eastin, J. D., J. H. Hultquist, and C. Y. Sullivan. 1973. Sorghum black layer. Crops & Soils 25:10-11.
Sullivan, C. Y. and J. D. Eastin. 1974. Plant physiological responses to water stress. Agricultural Meterology (in press)
Blum, A. and C. Y. Sullivan. 1974. Leaf water potential and stomatal activity in sorghum as influenced by soil moisture stress. Botanica 23:42-47.

17. Other considerations: No comment.

18. Recommendations: In order to understand physiological responses to the environment and environmental interactions it is necessary to accurately define the micro-environment of field grown plants. In this regard, consideration should be given to adding a micro-climatologist and soil scientist to work with the plant physiologists and geneticists at Nebraska. An additional plant breeder is also needed at Nebraska.

Prepared by: V. T. Walhood   Date: October 31, 1974

1. WRU: Number 501-5203-10590
   Title Cotton Production Practices

2. Location: U. S. Cotton Research Station, 17053 Shafter Ave., Shafter, CA 93263

3. Scientist's name, address, and telephone no.:

   Vilas T. Walhood, U. S. Cotton Research Station, 17053 Shafter Ave., Shafter, CA 93263, (805) 746-6391 and (805) 323-6153

4. Current SMY's at location: .15

5. Net Budget: FY 1975

   (a) Salaries: $43,892.88   (a) Operations: $4,100

6. Research Mission: Development of improved cultural practices for producing upland cotton in the Far West.

7. Research Objectives: Determine manner in which environment, genotype, cultural methods, and applied chemicals affect cotton plant yield and quality of lint and seed in the Far West. Develop improved production practices and increased yield and quality potential.

8. Status of Present Research: Narrow-row systems of cotton production are being compared with conventional systems, including studies on most adaptable row orientation, plant morphological characteristics, consumptive use of water, soils, and fertilizers, harvest aids and harvest machinery, yield and quality of fiber and seed. Morphological characteristics and plant environments in relation to interception of solar energy are being studied. Plant growth regulators will be applied to evaluate their influence on growth of cotton. Cultural and chemical harvest aid studies related to the fiber and seed yield and quality of commercial and experimental Acalas are continuing.

9. Significant Research Accomplishments: Two synthetic growth regulators sprayed on field-grown plants reduced the length of internodes without interfering with reproductive growth. The most satisfactory method of short-season cotton production was by reorienting the cotton rows from 38 or 40 inches apart to rows 32, 20, or 10 inches apart or to 2 rows 14 inches apart on 38-40-inch beds. Maximum interception of solar energy was achieved up to 30 days earlier by the narrow row configurations. Genotypes yielding over 1,000 lbs lint/acre had 94% open bolls by August 30 at Shafter; genotypes yielding over 1,200 lbs lint/acre had 94% open bolls on September 20 at WSFS. Yields over 1,000 lbs lint/acre were finger-stripper harvested on September 20 at Shafter. Yields over 1,200 lbs were finger-stripper harvested at WSFS on October 3 and had higher total yields. Fiber properties from finger stripper harvested narrow row cottons were equal to those of the same cottons (varieties and cultures) that were hand or spindle picker harvested.

   Yields from selections with super okra-type leaves were generally lower than normal leaf selections grown in narrow rows, but were higher than the standard SJ-1 on 40-inch rows. Three post-plant irrigations totaling 14.8 inches of water applied to narrow row cotton on a coarse soil (1.0-1.2 in/ft WHC) produced higher yields than 21.3 inches applied in 6 irrigations to conventionally grown cotton. Applications of nitrogen to the coarse soils at Shafter have not increased yield and have delayed crop maturity when applied to narrow row cotton.

10. Impact of Research on Science and General Public: Re-orientation of conventional 38-40" rows to 20", 10", or 2 rows 14" apart on 38-40" beds have increased the yield of lint and seed and permitted harvest operations to be completed 30 to 90 days earlier than the conventional production system; solar energy is intercepted more efficiently. Indications are that less water and fertilizer are required for the narrow row system. Timely and more appropriate land preparation is made available. Increased agricultural productivity is made possible by double cropping; forage or feed grains and cotton can be grown the same year.

11. Obstacles to Achieving Objectives:

    1. The one-variety law for cotton and its ramifications

    2. Lack of tools and machinery for a narrow-row system of production

12. Future Lines of Research for Emphasis: Field-scale and trade evaluations from the costs of production through spinning of the finished product.

13. Research, Facilities, and Personnel Needs: Same as No. 12

14. Extent of Cooperation: R. E. Johnson, U.C.-Davis; P. J. Knowles, U.C.-Davis; D. G. Grimes, U.C.-Davis (Parlier); H. Yamada, U.C.-Davis (WSFS); A. H. Hyer, USDA, Shafter; R. E. Curley, U.C.-Davis; J. H. Goss, U.C.-Davis; J. H. Miller, USDA, Shafter.

15. Recommendations: The engineering aspects of the system appear to pose a major problem. Included are the most adaptable row systems for planting and irrigation applications for the different soil types. Efficient harvesting machinery is a major problem. Cultural practices including entomological studies are necessary that establish a boll at the first possible fruiting position. Additional studies are needed in harvest-aid preparation of short-season cotton. New approaches to weed control in narrow row cotton are needed.

16. Other Considerations: None

17. Number of Publications in Past 2 Years: Five

    1. Varietal characteristics and irrigation practices as harvest aids in narrow row cotton. Beltwide Cotton Production Research Conferences-1972.

    2. Influence of short-season cotton harvest-aid procedures and method of harvest on seed cotton and fiber properties. Beltwide Cotton Production Conferences-1973.

    3. Plant populations, narrow row plantings and production efficiencies in the San Joaquin Valley. Beltwide Cotton Production Conferences-1973.

NATIONAL PROGRAM STAFF

Format for Providing Information for
ARS Photosynthesis Workshop

Prepared by L. Neal Wright Date October 14, 1974

1. Number and Title of Work Reporting Unit (WRU). None

2. Location(s). Tucson, Arizona 85719

3. Scientist's Name, Address, and Telephone Number.

L. Neal Wright
USDA,ARS Western Region
Department of Agronomy & Plant Genetics
University of Arizona
Tucson, Arizona 85721
(602) 884-1400 or 884-1977

4. Current SMYs Working on Photosynthesis at Your Location. None

5. Percent of Your Time Spent on Photosynthesis Research. Minimal

6. Net Budget. Not applicable at present.

7. Mission of Research. Not applicable at present

8. Objectives of Research. Not applicable at present

9. Status of Present Research. Not applicable at present

10. Significant Research Accomplishments (Be specific and brief).
Not applicable at present

11. Impact of Research on Science and General Public. Not applicable at present

12. Obstacles to Achieving Objectives. Not applicable at present

13. Future Lines of Research for Emphasis. Not applicable at present

14. Research, Facilities, and Personnel Needs. Not applicable at present

15. Extent of Cooperation--Names of Persons and Institutions.
Not applicable at present

16. Titles and Places of Publications in the Past Two Years.
Not applicable at present

17. Other Considerations.

A research proposal is being prepared for submission to the National Science Foundation. Co-Principal Investigators are L. Neal Wright and A. K. Dobrenz. Both are located at Tucson, Arizona. The proposed title is "Genetics of Solar Energy Conversion to Biomass by *Panicum antidotale* Retz." Dr. Dobrenz is a plant physiologist, Department of Agronomy and Plant Genetics, University of Arizona. The Department of Agronomy and Plant Genetics, University of Arizona is the institution through which the grant is to be established.

An additional effort includes species crosses to study the transmission of photosynthetic responses. *Panicum antidotale* is a C_4 plant. Three species of C_3 *Panicums* have been collected. Plants are being established and diallel crosses among the species will be attempted. After the crosses are successful, requests will be submitted to proceed with this potentially fruitful research.

18. Recommendations.

It would appear that research with a species would be the most productive at this stage of photosynthetic research. As I view the literature a minimum of knowledge has been established toward specific understanding of the photorespiration process and its inheritance.